THROUGH WONDERLANDS OF THE UNIVERSE

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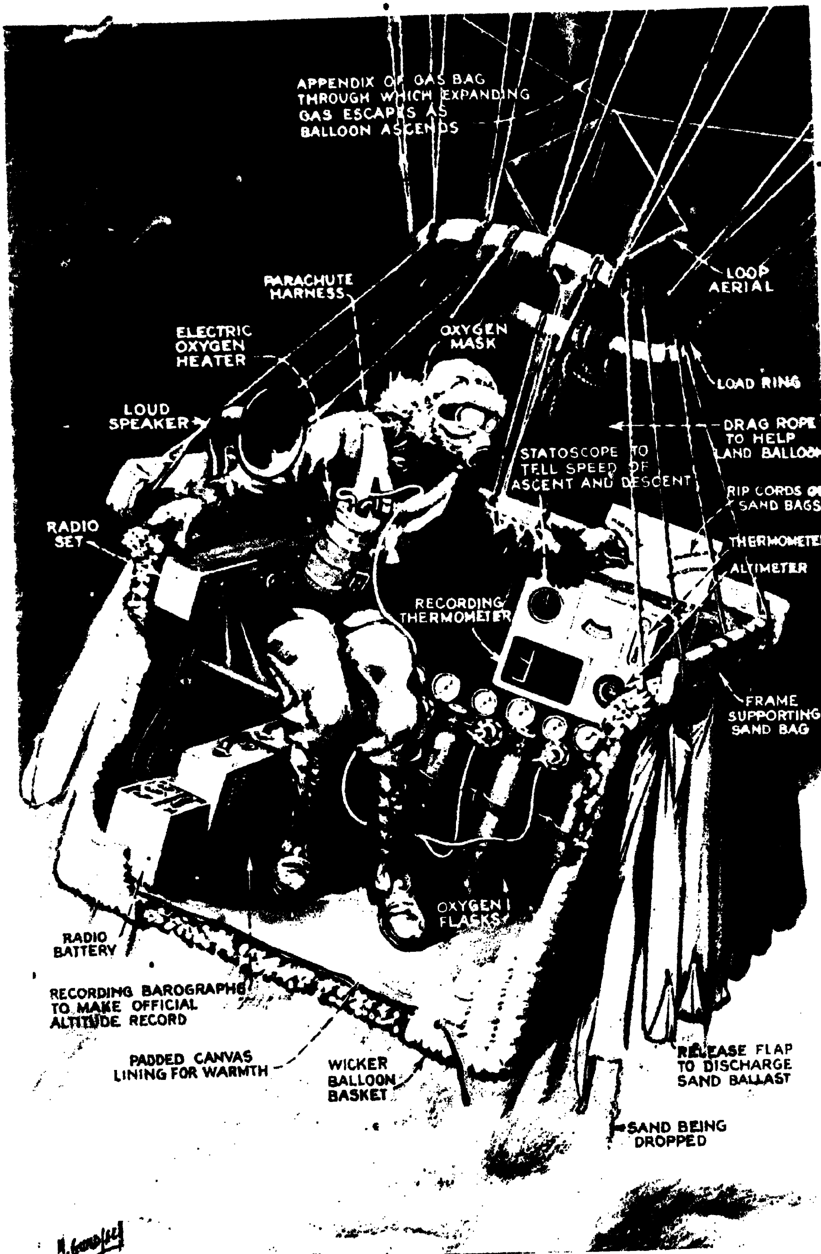

Capt. Hawthorne Gray's High-Altitude Balloon Equipment—pp. 205-206
(By Courtesy of the *Popular Mechanics Magazine*, Chicago)

THROUGH WONDERLANDS OF THE UNIVERSE

BY

R. K. GOLIKERE

BOMBAY:
D. B. TARAPOREVALA SONS & CO.
KITAB MAHAL, HORNBY ROAD

Printed by M. N. Kulkarni at the Karnatak Printing Press, 318A Thakurdwar, Bombay, and Published by Jal Hirji D. Taraporevala for D. B. Taraporevala Sons & Co., "Kitab Mahal", Hornby Road, Bombay.

RESPECTFULLY DEDICATED

BY KIND PERMISSION

TO

SIR JAMES HOPWOOD JEANS

M. A., D. SC., LL. D., F. R. S.

THE EMINENT

PHYSICIST-MATHEMATICIAN-ASTRONOMER

TO WHOSE

INSPIRING WRITINGS AND LECTURES

THE AUTHOR OWES

HIS PRESENT HUMBLE EFFORT

PREFACE

THE chief aim of this book is to convey, concisely and as simply as possible, an idea of the principal features of the various divisions of the material universe and of the more striking phenomena occurring in them. It is not a learned treatise, but a simple elementary study, a modest attempt to awaken a taste for Science among those who ordinarily take little interest in it. The book is therefore primarily intended for laymen, who cannot be expected to wade through a large mass of technical literature in search of scientific information of a general character. It is hoped at the same time that junior students of Science will find in it a handy volume for casual reference.

To start with, the subterranean wonders of Nature and the results of human endeavour to explore or exploit the depths of the earth's crust are placed before the reader, and he is introduced step by step to the constitution and disposition of the rocky framework of the globe and to the probable physical state of its interior down to the central core. The mysteries and marvels of the ocean are unveiled next, inch by inch so to say, from a level high above its surface to its deepest floor. Short descriptions are given of the more important and impressive of oceanic phenomena, with explanations where necessary, along with references to the extent of penetration made by man so far into the depths of the sea. The reader is finally taken on the wings of imagination on a pilgrimage, stage by stage, up the ladders of the earth and of the regions beyond to the 'Roof' of the Universe. He is made to fly, more often than not, at a sharp tangent from one object to another, from one place, country or continent to another, from the scene of one phenomenon to that of another, from one milestone in space to another, and from one heavenly body to another. With such a plan

of arrangement, he should not be surprised if the subjects of any two consecutive items in the earlier chapters are found to be in their nature as poles asunder. His attention is drawn, from time to time, during his long climb to the summit of the heavens, to the approximate height above ground or sea level or distance from the earth, as the case may be, of his observation-point, at which he may still hear certain terrestrial sounds or may feel sensations of a weird nature or observe objects, things and phenomena as multitudinous in their variety and diverse in their character as the universe is able to unfold. His attention is also drawn to points in mid-air from which any noteworthy feats have been accomplished and to milestones in space reached by disease-germs, insects, birds, airmen, unmanned human contrivances and other objects.

As will be readily imagined, the materials for a book on so comprehensive a subject have had to be gleaned from numerous fields of knowledge. A considerable part of the material is drawn from scientific and other journals and, to the best knowledge of the author, is not embodied in books so far published. Every branch of knowledge dealt with or touched upon is so vast that it may well demand even from the savant the undistracted and devoted labour of a lifetime. Under the circumstances it would be too much to expect that the author has been able to steer clear of errors. He therefore craves the indulgence of the erudite scholar and scientist in regard to any errors they may detect, and he will be grateful if any such are pointed out.

Some, if not many, of the values relating to depths, heights, distances etc. are liable to alteration from time to time in the light of fresh achievements in the respective branches of science. It need hardly be added, therefore, that a work of this character will require to be revised and brought up to date, and if possible amplified or enlarged, at proper intervals. The publication of revised editions of this work in the future will wholly depend upon the measure of encouragement and support extended to it.

A list of the principal books and journals consulted is appended, as also an Index. Even a cursory glance through the latter should suffice to show the wide variety of the topics dealt with, a variety which encourages the hope that there will be few readers who will not find in the work something or other to awaken or stimulate their interest.

The author is much indebted to Mr. K. R. Gunjikar, M. A. (Cantab.), B.Sc., Professor of Mathematics at the Royal Institute of Science, Bombay, for the trouble he took to go through the manuscript and for his valuable suggestions and help, especially regarding some of the astronomical items and mathematical portions of the work; to Rao Bahadur H. Nárayaná Rao, M.A., one-time Professor of Geology at the Presidency College, Madras, for his kindness in looking into such of the geological items as were referred to him for verification and revising them where necessary; to Dr. Nazir Ahmad, M.Sc., Ph.D. (Cantab.), Director of the Technological Laboratory at Matunga, Bombay, for kindly supplying the most recent information respecting a few items of physics; to Moulvi Sayad Sulaiman Nadvi, Director of the Shibli Academy at Azamgarh, United Provinces, and a distinguished Arabic scholar, for a list of stars bearing Arabic names with their meanings; to Mīmāmsāshirômani Pandit Vāman Shastri Kinjvadekar, Superintendent of the Mīmāmsā Vidyālaya at Poona, for some of the Védic references in this book; to Messrs. Ingersoll-Rand (India) Ltd., Bombay and Calcutta, and Messrs. Scott & Saxby, Ltd., Well-boring Engineers of Calcutta, for a considerable amount of information about Sub-artesian Wells sunk in India; to the editor of the *Illustrated Weekly of India*, Bombay, for permission to give the substance of an interesting article on the aspirations of a famous rocket scientist, which appeared in that journal; to the editor of *Everyday Science & Mechanics*, New York, for similar permission in connection with an article in that magazine from his own pen, relating to a remarkable scheme worked out by another noted rocket

expert; and last but not least, to two well-known Doctors of Science who prefer to remain anonymous—to the one for revision of some items of physics, and to the other for similar assistance as also for his consistent encouragement and appreciation which have sustained the author throughout the arduous preparation required for a work of the present character based on a plan hitherto untried.

His thanks are also due to the authorities of the University of Bombay for kindly allowing him the use of its library.

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BOMBAY (*India*)

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Universe designates the entire mass of worlds, with everything associated with them, comprehending all stars, planets, satellites, comets, etc. regarded as one system. *Creation*, in its most extended sense, is nearly synonymous with *Universe*, differing from it principally in not comprehending the Great First Cause, and the idea of space. —*John Ogilvie*

Was it by mere chance that these blind parts of matter, floating in an immense space, did, after several justlings and rencounters, jumble themselves into this beautiful frame of things? —*Dr. J. Scott*

Creation lies before us like a glorious rainbow, but the Sun that made it lies behind us, hidden from us. —*Jean Paul*

Nature forces on our heart a Creator. —*Ibid*

Nature is the glass reflecting God,
As by the sea reflected is the sun. —*Young*

Nature is the only book that teems with meaning on every page.
—*Goethe*

The heaven, the air, the earth, and boundless sea,
Make but one temple for the Deity. —*Waller*

The universe is the realised thought of God. —*Carlyle*

Sky is the part of creation in which Nature has done more for the sake of pleasing man, more for the sole and evident purpose of talking to him and teaching him, than in any other of her works, and it is just the part in which we least attend to her. —*Ruskin*

The material universe is a great work of art, full of design and plan, though I do not know what it means. That universe as a work of art demands a Creator, a Being who is in and of the spiritual world and, we believe, rules that spiritual world to some purpose. — *Sir Oliver Lodge*

Life is girt all round with a zodiac of sciences, the contribution of men who have perished to add their point of light to our sky. . . . . . These road-makers on every hand enrich us. We must extend the area of life and multiply our relations. We are as much gainers by finding a property in the old earth as by acquiring a new planet. — *Emerson*

Science always goes abreast with the just elevation of the man, keeping step with religion and metaphysics; or, the state of science is an index to our self-knowledge. — *Ibid*

Science is teaching man to know and reverence truth, and to believe that only so far as he knows and loves it can he live worthily on earth, and vindicate the dignity of his spirit. — *Moses Harvey*

Scientia nihil aliud est quam veritatis imago. (Science is nothing but an image of the truth). — *Bacon*

Scientific, like spiritual truth, has ever from the beginning been descending from heaven to man. — *Disraeli*

The greatness of God is shown in the perfection of the Universe. Study science and you will find how perfectly everything fits in. That is the real miracle of life. — *Prof. A. M. Low*

Science is an ocean. It is as open to the cock-boat as the frigate. One man carries across it a freightage of ingots; another may fish there for herrings. — *Bulwer Lytton*

HINTS

'Altitude', 'Elevation' and 'Height'

These are commonly used by writers as almost interchangeable terms. In this book, as a rule, 'altitude' is used in the restricted sense of height above sea level which anything reaches, not on *terra firma*, but in the air or sky; 'elevation' in the sense of height above sea level at which an object is situated on any part of the earth's land area or which it reaches thereon; and 'height' to denote the vertical distance risen or reached by anything above the surface of the earth, whether that surface is land or water, or whether, in the case of land, the ground lies below, at or above sea level. Thus a bird which soars into the air from the top of a mountain cliff situated 2,000 ft. above sea level and later happens to reach a vertical distance of 300 ft. right above the cliff, has reached a *height* of 300 ft., but an *altitude* of 2,300 ft. Here the cliff stands at an *elevation* of 2,000 ft. Wherever any doubt might arise as to the exact import of the term used, the sense is made clear either in the text of the item or in the Note annexed to it. After certain altitudes it becomes no longer necessary to observe these subtle distinctions, so that thereafter these terms need not always be interpreted in the sense defined above.

HINTS

Easy way of remembering the values of 'illions'

A million	=	10^6			
A billion	=	10^9	–	Latin	*bi*–, twice
A trillion	=	10^{12}	–	„	*tres*, three
A quadrillion	=	10^{15}	–	„	*quatuor*, four
A quintillion	=	10^{18}	–	„	*quinque*, five
A sextillion	=	10^{21}	–	„	*sex*, six
A septillion	=	10^{24}	–	„	*septem*, seven
An octillion	=	10^{27}	–	„	*octo*, eight
A nonillion	=	10^{30}	–	„	*nonus*, ninth; *novem*, nine
A decillion	=	10^{33}	–	„	*decem*, ten

It should be easy to remember the values signified by these terms. To find out readily how many ciphers an 'illion' contains, multiply by 3 the number indicated by its prefix and add 3 to the product. The French notation for these 'illions' has been adopted throughout this book, as it is found more convenient for mathematical purposes.

There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy.

— SHAKESPEARE

To recount almighty works
What words or tongue of seraph can suffice,
Or heart of man suffice to comprehend?

— MILTON

CHAPTER I

The Earth And Its Interior

> Bid Atlas, propping heaven, as poets feign
> His subterranean wonders spread.
>
> *James Thomson*

According to the tidal theory of the genesis of the solar system, a gigantic star, hundreds of million years ago, approached the sun so close as to raise two enormous tides on the surface of the latter body. The resulting protuberances, says Dr. Jeffreys, were greatest at those points of the sun which were nearest to and farthest from the star. 'When the distance between the two bodies became sufficiently small,' he explains, 'the tendency to disruption due to the difference between the attractions of the star on the two opposite sides of the sun became greater than the sun's gravitation could counteract, and a portion of the sun was torn away. This afterwards condensed to form the planets and satellites.' This theory has received wide support and been developed in recent years, and it is considered probable that the matter ejected from the sun almost at once gathered into nuclei which, proceeds Jeffreys, 'continued to move outwards but were deflected by the star and thus proceeded to move around the sun in one direction and nearly in one plane.' When the earth was born, it was in a gaseous state like the other members of the solar system. According to Jeffreys, again, its liquefaction must have become complete within 5,000 years of its formation and it probably became solid within about 10,000 years thereafter. When the earth was still very hot and fluid, it is believed that it must have had a fairly uniform surface owing to its rotation about an axis. As it cooled, it contracted, and this process has caused its crust to be, in the words of Mr. Clive Barnard, crumpled and cracked and folded in the same way as the peel of a long-stored apple wrinkles owing to the shrinkage of the substance of the

fruit. During this long process the weaker parts of the crust which lay deep underground have been forced up to the surface. The age of the earth as estimated by Jeffreys is between 1,300 million and 3 billion years.

We shall now deal briefly with the composition of the earth's crust. The materials of which it is composed are called by the general name of *rocks,* a term wide enough in its scope to include the hardest granite as well as the softest clay. The rocks formed at the earliest period in the earth's history occupy the deepest portion of the crust, and their characters indicate that they must have been formed under intense heat and pressure at a time when the earth was so hot that its water had probably not yet been differentiated. These rocks are known as Azoic (Gr. *a,* negative, *zoe,* life), since they are destitute of any vestige of organic life. Above this zone which forms the core of the crust are found rocks of another class in which are embedded the remains of plant and animal organisms, a fact which leads to the inference that by this time the earth had sufficiently cooled at the surface, its water-vapour had condensed and life had already appeared on the globe. In accordance with the age or character of the organic remains embedded in these rocks, geologists classify the various zones or strata as follows: (1) Palaeozoic (Gr. *palaios,* ancient, *zoe,* life) or Primary, the lowest division of stratified groups, (2) Mesozoic (Gr. *mesos,* middle) or Secondary, (3) Cainozoic (Gr. *kainos,* recent) or Tertiary, and (4) Post-Tertiary or More Recent. These classifications in turn have their respective sub-divisions. We may digress here for a while to show how these different divisions are associated with the Ages of the respective forms of animal life that appeared on the earth in the long course of life's evolution and culminated in its crowning piece, the most highly organized form of life—Man.

Palaeozoic	Age of Invertebrates Age of Fishes and Amphibia	These include ancient and extinct forms of life.
Mesozoic—	Age of Reptiles and Birds, intermediate forms of life.	
Cainozoic—	Age of Mammals, exhibiting recent forms of life other than Man.	

Post-Tertiary—Age of Man.

> Then, that no region of the universe
> Should void of life remain, ...
>
> The seas became th' abode of glittering fish,
> Earth took the beasts and mobile air the birds.
> A holier animal was wanting still
> With mind of wider grasp, and fit to rule
> The rest. Then man was born.
>
> OVID: *Metamorphoses*

As applied to India, the Palaeozoic division is associated with the Dravidian Epoch, and the Mesozoic and Cainozoic divisions with the Aryan Epoch.

Those rocks that have been formed by the consolidation of molten masses, molten because of the intense heat in the earth's interior, are termed *igneous* rocks. The liquid substance within the earth's crust that finally solidifies as rock is called *magma.* Those igneous rocks which have gradually cooled at considerable depths under high pressure are called *plutonic* or *abyssal* rocks, and those that have been thrown up to the surface and solidified more quickly are known as *volcanic, eruptive* or *effusive* rocks. Granite is an example of the plutonic type. Rocks formed by the consolidation of the coulées or lava-flows from volcanoes come under the second type, of which basalt affords an instance. Besides these two, there is a third type which is structurally intermediate between them. They have risen far up but failed to reach the surface, and have consolidated in fissures at no great depth. These are called *intrusive* or *hypabyssal* rocks.

We come next to what are classed as *aqueous* rocks. The broken or loosened fragments of the rocks already consolidated on dry land often go to form what are known as *fragmental* or *detrital* rocks. As examples of these may be mentioned siliceous rocks like *conglomerate* or pudding-stone—large, rounded fragments consolidated from gravel—and sandstone, and argillaceous or clay-rocks like claystone, mudstone, shale, and slate which is formed by clay subjected to enormous compression by earth movements. Huge quantities of the ancient rocks, when exposed to the surface,

slowly wear away by the action of rain and rivers and through other agencies, and their debris or waste material is carried in suspension by the water until at last it settles down in vast quantities. In this way sediment is deposited in layers called *strata*, and it gradually integrates into a solid mass under the pressure of the later formed overlying sediment. Rocks thus formed are called *sedimentary* or *stratified*. Though in their origin superficial, they may be taken underground as the result of earth movements. Similarly, underground forces at times bring about a reverse movement in some rocks. The familiar granite, though in its origin deep-seated, may and does appear at the surface as the result of the combined action of earth movements and the removal of the overlying mantle of rock by surface or atmospheric agencies. There is another group of aqueous rocks called *organic*, which are formed, not from the refuse of ancient rocks but mainly by the agency of vegetable and animal life. Organic rocks are sub-divided into two sections: *calcareous*—those formed by the agency of animal life; and *carbonaceous*—those formed by the agency of plant organisms. Calcareous rocks are composed for the greater part of shells and the debris of shells of countless minute animals that once lived in the ocean. With their death their remains descended to the bottom and petrified there in the long course of time. Some species of limestone which include chalk, the softest and finest variety of limestone, belong to this section. Of carbonaceous rocks coal is the most important example. It is formed from vast masses of vegetable matter which lay buried for ages under sedimentary deposits and were there subjected to pressure, heat and chemical action. Sometimes the organic remains of animal and vegetable life become embedded in the strata of the sedimentary layer and either remain there partially preserved or become petrified. Such remains are termed *fossils*. Chalk strata are characterized by remarkable fossils, the most distinctive being the giant lizards or reptiles of the Secondary Epoch such as the iguanadon, the megalosaurus and the pterodactyl.

Of vegetable fossils coal furnishes a typical example. There is yet another group of rocks the materials whereof are generally minerals obtained from other rocks by chemical agency. Rock-salt and certain kinds of limestone and iron ore come under this group.

All this information about rocks, tedious though it may appear, is essential for even an elementary idea of the nature of the earth's crust, and besides, many of the technical terms used appear in later explanations. This may not be exactly a wonderland, but we hope our fellow-pilgrims will not suspect that we take this rather circuitous route to regions higher up merely to show that the path to heaven is rugged!

There is a black opaque mineral with resinous lustre, called Tachylyte, which occurs in trap-rock, a sub-species of the igneous class, and was formed for the first time at an age somewhere between the periods of the formation of granite and the ancient volcanic rocks. In very thin sections it is brown and translucent. It derives its name from the ease with which it fuses under the common blow-pipe. The conditions under which it is found indicate that it has been formed by the rapid cooling of what was originally basalt in a magmatic state. Owing to its glassy appearance it is also called Glassy Basalt. It constitutes practically the whole content of the lava erupted by volcanoes as in the Hawaii Islands, and is ejected also in the form of cinders or scoriae by basaltic volcanoes like those of Iceland, Stromboli and Etna. Another important sub-species of igneous rock is the Diorite, a crystalline granular rock.

Certain rocks contain a mineral called chrysolite, a yellow or green precious stone, of which olivine, a mineral of olive-green colour, is a sub-species. Chrysolite and its sub-species are harder than glass, but not so hard as quartz, and are often transparent but sometimes only translucent. There is a rock named Peridotite of plutonic origin which is composed chiefly of olivine but has a dark colour. A sub-species of peridotite named Dunite shows in its composition a considerable preponderance of olivine

over all other minerals, so that it is an almost pure olivine rock.

The igneous and sedimentary rocks have in many cases greatly altered their nature under the influence of subterranean heat, high pressure, earth movements or other forces. They are then called *metamorphic* rocks, and the change undergone by them is known as *metamorphism*. They generally occur in a less or more crystalline state. For instance, quartzite is a crystalline species of sandstone, and marble a compact crystalline variety of limestone. The most widely distributed rocks of the metamorphic type are gneiss and schist. The crystalline layers of the latter rock are closely set and easily split, while those of the former, which is a metamorphosed form of granite, are of coarser grain and not so distinct. Eclogite, an important kind of rock, is considered to be normally derived from rocks of basaltic composition by metamorphism at great pressures. It consists largely of garnets, the red variety, and among the other minerals present the principal one is smaragdite, a mineral of light grass-green colour.

Professor Reginald A. Daly puts forward the theory that the crust below the ocean must be composed of rocks different from those which constitute the continents, for the reason that not even a single piece of granite has so far been found in any of the hundreds of volcanic islands in the Central Pacific, a quarter of the area of the whole earth. It is probable that the suboceanic crust is made up of denser materials than those below the continents. This view is based on what is called the *principle of isostasy*. Since over 7/10ths of the earth's surface consists of water—and this is mostly concentrated in the southern hemisphere—the globe would be 'top-heavy', that is, would not be in stable equilibrium as it rotates, if the materials below the ocean were not denser than those under the continents. This equilibrium is called *isostatic equilibrium*.

That branch of geology which is concerned with the composition and classification of rocks is called petrology, and the department of biology which treats of fossil organic

remains, a branch in which both geologists and biologists are equally interested, is known as palaeontology. But there are wheels within wheels. That section of the last-named science which deals with the fossil remains of animal organisms is termed palaeozoology, and the sub-branch which concerns itself with fossil plants or vegetable remains is named palaeophytology or palaeobotany.

The earth's equatorial diameter is 7,927 miles, polar diameter 7,900 miles and mean diameter 7,918 miles. The earth is flattened at the Poles and bulged at the Equator and in shape, therefore, it is an oblate spheroid. As its surface is curved, the distance from Pole to Pole is represented by the length of a semi-circumference connecting the two Poles and amounts to about 12,414 miles. The superficial area of the whole earth is 199,199,625 sq. miles, of which the land area measures 58,160,938 and the water area 141,038,687 sq. miles. The earth thus consists of about 29 per cent land and 71 per cent water.

With these brief introductory remarks about the earth, its origin, constitution etc., we start on our great pilgrimage through the universe. We propose first to pierce the crust and descend deep down to the bowels of the earth. But, before doing so, let us hark back to the poet's lines quoted at the head of this chapter. Has Atlas any subterranean wonders to reveal? If so, let us see if there are any which we can visit and study without bringing our boring tools and instruments into operation!

(1) An idea suddenly flashes across our mind. We remember what we learnt in our school-days—that there is a mountain chain in northern Africa named after that mighty Titan of Greek mythology. We decide to commence our subterranean pilgrimage from the plateau of one of these mountains. On arriving there we make a cursory survey of the ground. We observe a number of small pits covering the region and go down one of them. We find to our surprise distinct evidences that they are not natural, and are beginning to wonder what we may come across at the bottom, when hark, a chorus of angry voices evidently swearing at us trespassers suddenly assails our ears! What marvel is it that Atlas has in

store for us at so early a stage? What on earth could these pits represent?

Underground dwellings of the world's strange tribe of 'Hole-men' } *Depth* 12-15 ft.

Note.—Incredible as it may seem, there is a place in the world whose population, numbering no fewer than 11,500, live in holes! It is the 'town' of Matamata, 3 sq. miles in extent, lying in the Atlas Mountains. The whole territory is covered with circular tunnels, 12 to 15 ft. deep, which are provided with steps leading to the underground town. Rooms have been dug in hard clay. These hole-men are sportingly called 'climbing *troglodytes*', a Greek term meaning 'cave-dwellers'. This is not the only place in northern Africa where hole-men are to be found. In the Sahara Desert, two miles from Taoudeni, a town very difficult of access, is a group of salt-mines called 'The Hell of the Salt', worked by slaves. These workers dwell in holes dug just under the ground level. Two intrepid Frenchmen who recently visited the place entered one of these holes out of curiosity, and in so doing had to bow low and in places even to creep. These discoveries remind us of those prehistoric races of the earlier and the more recent periods of the Stone Age who, archaeologists tell us, lived in caves and subsisted on shell-fish and the flesh of wild animals, and about whose physical appearance and social habits some interesting literature, accompanied by illustrations, appeared in certain journals a few years ago. But we were hardly prepared for the discovery that some of their 'ancestors'—or rather a whole colony of them—were still in the land of the living!

Africa is a museum of prehistoric ethnological exhibits. For, while the North holds up these hole-men as a living wonder of the world, specimens that mark, from the habitation point of view at any rate, the next stage in the evolution of the human race have been found in the East. There is a tribe in East Africa whose members live in caves high up on the mountain side. Mr. A. Copping, a British traveller, paid a visit to these interesting cave-men in 1931. They have been living for generations in these primitive dwellings, aiming at no higher civilization.

Herodotus (born about 484 B.C.) tells us of a race of Troglodyte Ethiopians in inner Africa, 'very swift of foot, living on lizards and creeping things, and with a speech like the screech of an owl.' The present-day hole-men and cave-men of Africa must have a long history behind them extending over a countless number of years.

It may not be generally known that a number of people, though for special reasons, used to live in holes a few centuries ago in no less a country than England. During the reign of the Tudors and the early Stuarts the great Windsor forest was infested with wolves, which had become so great a terror that many of the peasants in this region dwelt in holes in the ground as a measure of protection!

(2) World's Largest Subterranean Lake yet discovered: Distance underground } 152 ft.

Note.—Brief particulars of this lake appear in *The Sphere* of 5th December 1931. It was discovered only in that year by a party consisting of Professor Alviani of Trieste and two other scientists. The lake lies near the Grotto of Postumia in Italy and is 300 ft. long and 180 ft. broad. The route is a most arduous one and had to be negotiated by a rope-ladder. The last portion of the path being extremely narrow, the party had to crawl along a passage barely 2 ft. high. The lake is remarkable not only for its size, but also for the slope of its roof which varies from 2 to 150 ft. above the water surface.

(3) World's most remarkable Subterranean Rivulet—Echo River near the Ruins of Kentucky, U.S.A. } 360 ft. underground

Note.—It is a brook about ¾ mile long. According to the *Encycl. Br. (1929)*, it is 20 to 200 ft. broad and 10 to 40 ft. deep, and is covered by a symmetrical vault 15 to 35 ft. high. 'It is famous for the resonance of the tones given out by its vibrant stone which reverberate for from 10 to 30 seconds along its vaulted gallery.' Boats can traverse this stream for half a mile, says *The Sphere* of 5th December 1931, and a ride over its clear waters is one of the most unique experiences in the world. 'Nowhere else can it be duplicated. Nearly all the river is one vast resonating chamber.'

A river sometimes abruptly plunges into a vertical pit or cleft and resumes its course in a cavern below. A notable example occurs at Inglesborough in Yorkshire. Here the river, after hurling itself into Gaping Ghyll, 365 ft. deep, flows underground to a considerable distance until it emerges again from a cavern known as Clapham Cave.

(4) World's most wonderful Subterranean natural Pillared Halls } About 690 ft. underground

Note.—A discovery of great interest was made in 1931 in the Gorges du Verdon on the southern boundary of the Basses Alpes (Lower Alps) Department of France. These gorges have long been famous for their picturesque precipices, many of which are still unexplored. In 1931 the Mayor of Eguilles with a small party went on an exploration trip to this region. They found by means of a lead line a shelf of rock at a depth of 75 ft. and went down to it. There they discovered a deep pit walled by massive rocks and descended into it to a depth of 120 ft. Coming back to the top they set up a depot of ropes, rope-ladders, axes and powerful acetylene flares. The Mayor let himself down again about 240 ft. and established there another store of climbing equipment. He went down alone into the dark depths for a distance of 450 ft. On alighting he discovered the entrance to a magnificent cave containing five great halls 'pillared by white stalactites', and he describes it as 'a veritable fairyland palace'.

Stalactites are conical or cylindrical fragments hanging from the roof of a cavern and produced by the filtration of water in which particles of lime-

stone are suspended, through fissures and pores in the rocks. When the water evaporates, it leaves behind a calcareous deposit which, owing to continued trickling of water, gradually becomes a pendent mass like an icicle. Some of the water drops on the floor and results in the formation of similar masses which are known as *stalagmites*. These sometimes form continuous sheets and often rise in conical masses which meet and blend with the pendants above. When the stalactites and stalagmites are so fused together, they are called *stalactitic columns*. It must be columns so formed that 'pillar' the subterranean halls described above.

There are also stalactites of ice. They often closely resemble those in limestone caves and are found in the great ice caves which occur in the Arctic and Antarctic regions.

While there are numerous stalactite caves in the world, only one is known which contains coloured stalactites. It is the 'Fairy Grottoes' near the old city of Sealfeld on the river Saale in Thuringia, Central Germany. Among its other attractions are a number of mineral springs, some of which are strongly radio-active,* which have been used for some years with excellent results in the treatment of gout, rheumatism and nervous disorders. It was assumed that radium emanation must also be proceeding from the rocks through which this spring water flows, and tests conducted through a whole winter revealed a high degree of radio-activity in the air in one cave connected with the uppermost of the three levels of the grottoes. This cave is now being equipped as an 'emanatorium' as it is called, and will be the first subterranean health-resort in the world.

(5) Bombay's nearest Artesian Well—the one at Viramgam, Ahmedabad District } Depth 776 ft.

Note.—An artesian well is a deep, vertical, cylindrical hole bored into the ground through a series of strata to a water-bearing stratum composed of sand, sandstone, chalk or other calcareous material, and enclosed between two impervious layers of clay. Wells of this class are usually sunk in areas where the underground permeable stratum is bent into a basin-shaped curve and crops out at the surface of the ground. Rain-water falling on the exposed edges of such a layer percolates through the porous bed and collects at the bottom of the basin, forming an underground reservoir, so that when the boring instrument reaches this pool, the water rises in a constant stream to the surface of the soil by natural hydrostatic pressure and generally spouts up several feet above it. A brief description of the type of drill commonly used nowadays in sinking artesian wells appears in the next item. The boring of wells of this class is not always easy work. The drilling rod sometimes breaks after piercing a great depth, and the removal of the broken parts which is necessary to permit of deeper penetration, is extremely laborious and sometimes impossible.

Artesian wells have been bored in ancient times by primitive methods in several countries, and distinct traces of them have been found in China,

* For explanation of this term *vide* Chapter VI, Item 1.

Persia, Turkey, Egypt and even in the great Sahara Desert. Springs of this class have been sunk during the past 100 years in various parts of the world. The French Government has bored a number of them in Sahara in the vicinity of Algeria, to depths of 150 to 800 ft. The Sahara Artesian Basin supplies over 100 million gallons of water per day, and several barren tracts have been converted into fertile land through these wells. From some of the subterranean pools which feed these wells the water brings up small fish, river-crabs and fresh-water molluscs.

The number of artesian springs bored in India is very small, though we have no information as to their approximate number. Nor have we been able to ascertain the depth to which the deepest of them has been sunk. The artesian well nearest to Bombay is the one at Viramgam, a station on the B. B. & C. I. Railway, 350 miles to the north. It was sunk in 1915-16. The water comes up at a temperature of 40° C. (104° F.), which remains constant.

(6) Deepest-known Sub-artesian or Bore Well sunk for water in India—the one at Mehsana, Baroda State — 935 ft.

Note

This well belongs to the B. B. & C. I. Railway and was bored in 1927. It is 6 in. in diameter throughout and supplies 10,000 gallons per hour. Of late years hundreds of wells have been drilled for water in different parts of India. Two 8-inch wells, each 500 ft. deep, were bored in the Alkali Works at Dhrangadhra, Kathiawar, in 1927. They yield more than half a million gallons per day, sufficient for the entire requirements of the Works. Similar wells have been sunk for industrial and agricultural purposes in the Dhrangadhra State. At Luvaria Farm, a 4-inch well, 300 ft. deep, gives a supply of 20,000 gallons an hour throughout the year, and the yield from another at the near-by Huzur Palace is 10,000 gallons per hour. A large number of small bore holes have also been put down in the kitchens and bath-rooms of houses in many parts of Kathiawar, particularly in places like Dhoraji and Batwa, where there is a large Mahomedan population. These wells are highly appreciated by purdah families. The Industrial Engineering Section of Madras, a Department which has been in existence for some years, has sunk at least 41 bore wells in the Presidency—20 in South Arcot District, 10 in East Godavari, 9 in West Godavari and 2 in Vizagapatam District. In a single village, Kavanur, a station on the M. & S. M. Railway, there are 8 such wells within a few yards of one another,

and it is stated that they yield the second largest sub-artesian supply of water in the world. The Department of Industries & Commerce in Mysore State has, in consultation with the Agricultural Department, been active during the last few years in boring wells in various areas which used to suffer from scarcity of water. The number of such wells in the State sunk up to the end of June 1931 was 140, their aggregate depth being 12,658 ft., an average of 90 ft. per well, and the total amount spent on them being Rs. 111,962 or an average of Rs. 8–13–6 per foot of depth. 5 wells bored at Tiptur yield 14,000 gallons an hour. In the town of Dodballapur 3 wells have been sunk, and a scheme has been prepared for pumping out water by air-lift, a system briefly described later, and the motive power will be electricity. The bore wells of Madras and Mysore have been instrumental in bringing thousands of acres under cultivation and providing several places with an abundant supply of good drinking water all the year round. The second deepest bore well in India is the one at Rāwalpindi (Punjab) which belongs to the North-Western Railway. It is 900 ft. in depth. The same Railway has sunk elsewhere a 10-in. well which yields 48,000 gallons per hour. A large number of bore wells have been sunk also by the Punjab Government.

We do not know the approximate number of bore wells sunk for water in the whole of India, but we have been able to ascertain that the total number exceeds 1,200. One leading firm of Boring Engineers and Contractors at Calcutta alone has sunk up to the end of May 1932 more than 600 wells in various parts of the country, from which over 36 million gallons of water are being pumped daily. The depths of these wells range from 100 to 450 ft. The water in most cases rises to within 30 ft. of the surface, so that the pumps here do not require to be carried to any great depth. Two artesian wells sunk by this firm in Sylhet (Assam) to a depth of 280 ft. yield each about 2,700 gallons an hour, the water rising 15 ft. above ground level. These extensive bore holes have been sunk for the use of Cotton, Jute, Paper and Rice Mills, Engineering, Steel, Gas, Paint and Chemical Works, Sugar, Ice and Aerated Water Factories, Oil Depots, Tea Gardens, Banks, Clubs, Colleges, Hospitals, Municipalities, Railways, Docks, Golf and Race Courses, Cantonments, Construction Camps and private residences.

The deepest water-well drilled in Asia that we have heard of is the one at Aden. It was completed in 1928 and is 1,655 ft. in depth. Its upper portion is 8 in. and lower one 6 in. in diameter. At the time of completion its yield was 8,000 gallons an hour. Two very deep wells bored by the North-Western Railway in Baluchistan deserve mention. One situated at Isatahir is 1,410 ft. deep, and the other at Dumboli is 1,585 ft. in depth.

More than 4,000 sub-artesian wells have been bored in Queensland and the central lowlands of Australia, some of them to depths of over 4,000 ft. The temperatures at the points of issue vary from 22°C. (72° F.) to boiling point. It is possible that still deeper water-wells exist in America, for in some cases very deep borings sunk for oil have yielded only water.

One of the most improved types of drill used nowadays for all boring purposes is the 'Calyx' Core Drill of the Ingersoll-Rand Company of New York, which has in recent years come into wide use in boring wells for water in India. Different classes of it are available to suit the power used to drive the drill—hand-power, steam-power, gasolene-power or electric power. One part of this instrument, the boring rod, which is hollow, performs the drilling work. As the operation progresses, water is pumped in through the hollow rod and into the other inner part of the drill, a cylindrical tube called the core barrel. As the cutter or shot bit—whichever of the two is used—rotates, it cuts a circular groove into the material under it. The water passes from the core barrel, under the bit or cutter, and rushes up through the space left around the barrel by the clearance on the bit, carrying with it the debris collected. When the top of the 'calyx' is reached, the upward speed of the water is considerably reduced on account of the wider passage afforded around the boring rod. At this point the heavier cuttings conveyed by the water drop into the 'calyx' on top of the core barrel plug. As the bit goes deeper underground, a cylindrical mass or core of the material drilled rises through the hollow bit into the core barrel. When this barrel becomes nearly full, the core is broken off, and the core barrel, along with the bit and the 'calyx' is hoisted to the surface. After the core and 'calyx' cuttings are removed, a length of boring rod is attached if necessary, the string of tools lowered into the hole and the process of drilling resumed. Where the hole has been started

through an over-layer of earth, gravel, sand or other soft material, strong iron pipes are driven into the bore hole as far down as necessary, so that it may remain open. After a certain depth has been penetrated, the pipe is either driven or rotated down according to whichever method is considered preferable.

The 'Calyx' Drill has been able to cut its way through any material so far encountered by it. It has burrowed its way through formations ranging from clay, shale, coal, slate, sandstone, limestone, and marble of almost every degree of hardness to granite, quartz-rock, jasper and even corundum, a crystalline mineral inferior only to the diamond in hardness, found in India and China.

The cost of boring of course varies with the nature of the soil and sub-strata, but it has been found to be considerably less than in the case of an open well dug in the same area. In the villages of Bikaner State (Rajputana), for example, the hand-dug wells are from 100 to 400 ft. deep, and bore wells here would have been much cheaper. Such wells are particularly useful in regions where the water-bearing stratum lies too deep to be tapped by an ordinary hand-dug well. Occasionally, however, even very deep boring fails to strike a water zone. At Amballa Cantonment (Punjab) the Military authorities carried the drill to 1,612 ft., but without success.

In a sub-artesian or bore well, unlike an artesian well, as will have been noticed, the water rises only up to a certain level, as the underground pressure which brings it up is not high enough to force up the water to the surface, so that it has to be pumped out for use. For pumping out a certain quantity in a given time, particularly where there is a group of bore wells, the Air Lift system perfected by the Ingersoll-Rand Company has been found to yield excellent results. The advantages of this system are that the yield of a well is often increased and the extensive aeration to which the water is subjected by compressed air adds to its purity. The main equipment for an Air Lift Pump installation consists of an air compressor, air receiver, air pipe lines and a pump or foot piece. The last-named device is used for connecting the air pipe with the discharge pipe in a well and also as a medium for admitting compressed air into a column of water.

In many countries there are large alluvial tracts—areas in river valleys and plains built up of thick accumulations and deposits of

sediment in the form of gravel, sand and occasionally clay, laid down by rivers when they overflow their banks. Most bore wells in India are sunk in alluvial tracts. When a well is to be sunk in such an area, the method employed is to sink casing pipes down to the water-bearing bed to prevent the soft strata caving in and choking the hole. As soon as water is struck, tubing consisting of various types of strainers is lowered into the bore hole and the casing withdrawn. Bore wells sunk in alluvial tracts are also called Tube Wells. Drilling to a maximum depth of 500 ft. is generally sufficient to reach the water-bearing stratum in these cases. Many tube wells have been sunk in the Gangetic Delta, each supplying up to 60,000 gallons an hour. In India chiefly, 'bore well' and 'tube well' are used as more or less interchangeable terms. In England, barring of course the river-plains—the dales and holms—which are alluvial, the strata are hard and do not cave in, so that the walls of a bore hole in that country remain intact and do not require to be cased. No strainers are used there, as the water is obtained from fissures in sandstone, limestone or chalk beds. Wells drilled in such hard formations can therefore be more properly called Bore Wells than Tube Wells.

Our object in giving all these particulars is to furnish as much information on the subject as possible within the limited compass of a book of the present kind and to stimulate public interest in India in the water-well boring industry which has come to stay in this country. There are large arid tracts, especially in the Deccan, Sindh and Rajputana, where an extensive sinking of such wells is sure to afford great relief to a population suffering for a considerable part of the year from scarcity of water.

There is still another class of wells known as Abyssinian Tube Wells. These can be sunk only in soft ground to depths of not more than 30 to 40 ft. They are usually 2 inches in diameter. They are successful only where the water-bearing bed exists at a shallow depth. The apparatus used is a cylindrical iron tube with a sharp point of solid tempered steel. The tube is perforated immediately above this point with a number of small holes. It is driven into the ground by means of a rammer or monkey till indications of water appear, when a small suction-pump is applied to the tube and the water

pumped up. With this apparatus only a temporary supply of water can be obtained.

Borings for oil, considerably deeper than the holes drilled for water, have been carried out in India by the Attock Oil Co., Ltd. in their oil-field at Khaur near Rāwalpindi. About 5 wells here have reached depths of 4,600–4,800 ft.

(7) Greatest Depth underground at which an 'Icy Air Well' or frigid compressed air has been met with in the course of drilling	1,171 ft.

Note.—Seven years ago, while searching for oil near Texas, U. S. A., the drillers encountered a rush of ice-cold compressed air, which spurted up from a well and continued to exude steadily. Later on another oil-well in the same area was found to send out the same remarkable product. A third well has been recently discovered in this region. This time the 'icy air' well' was tapped at a depth of 1,171 ft. The flow will be harnessed to supply power for boilers in the local industrial plants in place of steam, and will also be utilized for refrigeration of vegetables and other articles of food. It has been found that, in the hot season when the temperature at the surface was 90° to 100° F. (32·2° to 37·8° C.), the compressed air from the other two wells stood below zero.*

More recently prospectors in America found to their surprise streams of carbonic acid gas gushing out of several wells drilled in search of oil and free natural gas in the desert regions of Western Colorado and Eastern Utah.

(8) World's Deepest and Largest Subterranean Cave—the Carlsbad Caverns in New Mexico, U. S. A.	300-1,350 ft. underground

Note.—We learn from *Popular Science Monthly* of June 1930 that an expedition consisting of twelve explorers and scientists led by Mr. Frank Ernest Nicholson, author and traveller, visited these caverns in that year and spent several weeks underground. Descending by ropes into what was known for a long time as the 'Bottomless Pit', they found it to be a dark abyss 300 ft. deep with a dry river bed for its floor. Elsewhere in the cave they went down 1,350 ft. underground, the lowest level of its floor, and thus discovered it to be the deepest natural cavern explored. Among other objects of scientific interest, they found in the cave glistening stalactites and calc-spar crystals in variety and abundance. Wearing special helmets as a protection from the falling pieces of the stalactites, the explorers added about 10 miles of new passages to the 22 miles already well known. The most famous of the caverns, 750 ft. below ground level, is 'The Giant's Hall', which is probably the largest natural subterranean hall in the world. It is no less than half a mile in length and 348 ft. in height, with a maximum breadth of 400 ft. These caverns were formed by the action of subterranean waters in dissolving and eroding beds of rock-salt and limestone.

Another wonderful example of the wearing influences on limestone rocks, of water moving underground, is the great Mammoth Cave in Central Kentucky, U.S.A. Though the whole cave encloses an area of only about 80 sq. miles, scores of winding passages with domes, chambers and pits have been excavated to a collective extent of 150 miles without allowing for those which still remain to be explored. The main cave has its entrance in a forest ravine half a mile from Green River along whose banks open numerous passages of the cave. It varies from 40 to 300 ft. in width, and without including the subsidiary caverns and their branches extends to a length of 4 miles. The roof is 35 to 125 ft. in height. Picturesque cascades, lakelets and murmuring runnels, shining stalactites, stalagmites and stalactitic columns, sparkling floriform crystals of calcareous spar, all these add to the magnificence and charm of this wonderful underground region. The runnels are navigable to small boats for about five months in the year. A fine sandy beach leads from the last of the lakes to Echo River (*vide* Item 3), whose rippling limpid waters reflect the gorgeous stalactite festoons and other striking features of the galleries through which the brooklet runs. A cool temperature prevails throughout the cave, and the purity of the air is remarkable. The Mammoth Cave with its diverse attractions and labyrinthian formation is the grandest subterranean wonderland discovered. It is at the same time the most extensive cave known. It is estimated that the underground waters have been at work on the limestone strata since the Miocene or third period of the Tertiary Era in the geologic time-scale.

(9) Oldest Artesian Well in a great city—the one in the Grenelle Quarter of Paris } 1,795 ft.

Note.—This spring was commenced in 1834 and completed in 1841. The water that gushes up from it is of a constant temperature of 28° C. (82° F.).

(10) World's Deepest Artesian Salt-Spring—the one at Kissingen, Bavaria, Germany } 1,878 ft.

Note.—It throws up a column of water to a height of 58 ft. The temperature of the water is 19° C. (66° F.). An extraordinary feature of this well is that its ejecting force is due, not to natural hydrostatic pressure, but to that of carbonic acid gas which is generated at the junction of a gypsum bed with magnesium limestone at a depth of about 1,680 ft.

(11) Deepest Artesian Well bored in a great city—the one in the Passy Quarter of Paris } 1,923 ft.

Note.—Its diameter at the bottom is 2 ft. 4 in. It ejects a continuous stream of water at the rate of 5,582,000 gallons a day to a height of 54 ft. above ground level. The Passy and Grenelle Wells are among the sources of the city's water supply. The temperature of the water from both is the same, thus indicating a common source.

It is possible to erect artificial fountains which can throw up a column of water to considerably greater heights. The famous *Jet d'Eau* at Versail-

les in France rises to a height of 100 ft., and the great fountain at Chatsworth in Illinois, U.S.A., which holds the world's record, spouts a shower of water to a height of 267 ft.

(12)	Europe's Deepest Artesian Well—the one at Rochefort, France	2,765 ft.
(13)	Greatest Thickness discovered for an underground Rock-Salt Bed	At least 3,914 ft.

Note.—A deep boring was made at Sperenberg, 20 miles from Berlin, with the object of obtaining a supply of rock-salt. A bore hole 16 ft. in diameter was carried down to a depth of 280 ft. where the salt deposit began. After a further depth of 680 ft. was reached, the bore was reduced and the work continued till the great depth of 4,194 ft. was attained without the bottom of the salt bed being reached, and the bed has thus the extraordinary thickness of at least 3,914 ft.

(14)	World's Deepest Coal-mine—one of the mines in the Coal-fields in Belgium	4,000 ft. (*Encycl. Br., 1929*)

Note.—Coal strata occur in more or less horizontal beds, so that the entire coal in a field is obtained from a nearly uniform depth. In the case of mineral deposits, however, containing metals, the metalliferous veins are usually fissures in the crust, called *faults* or *dislocations*, caused by great earth movements. These faults often extend downwards through various formations and generally occur in slates, schists, granite and metamorphic rocks. They were at one time more or less open and formed subterranean channels for water filtering down from the surface, but are now closed up by mineral materials deposited on their sides. Metalliferous veins therefore run in descending masses unlike coal-beds. This is one reason why ores can be obtained from greater depths than coal. From the economic point of view it is considered improbable that coal will be worked at a depth exceeding 5,000 ft.

(15)	World's Deepest Artesian Well —the one at Putnam Heights, Windham County, Connecticut, U. S. A.	6,004 ft.= 1 m. 1 f. 21 yds.

Note.—It is 6 inches in diameter and yields 2 gallons of water per minute. The water spouts 4 ft. above the surface.

(16)	Probably the Third Deepest Working Mine in the world—a vertical shaft in the Kolar Gold Fields, Mysore State, India	6,380 ft.

Note.—These fields extend over a range of 40 miles and the mines are worked by electricity supplied from the power-house at the famous Sivasamudram Falls (400 ft. high) of the Cauvery River, 93 miles away. These mines supply nearly all the gold produced in India. The existence of gold in this region had long been known, and there are traces of operations in the

past conducted on crude methods. Mining was attempted in the reign of Tipu Sultan but without success. The first shaft was sunk near Oorgaum in 1875, and since then the mines have been steadily working and yielding good profit, the total output of gold up to now being of the value of nearly 70 million sterling. In an inclined shaft in the Champion Reefs Mine in these fields a depth of a little over 7,000 ft. has been reached.

(17)	Deepest Boring made in Europe—the one at Czuchow, Silesia	7,348 ft. (*Encycl. Br., 1929*)

Note.—A number of deep holes have been drilled in Europe for geological exploration or prospecting purposes, and also for observation of the increase of temperature in the deeper parts of the earth's crust.

The following are some of them :—

At Buda Pesth, Hungary	3,160 ft.
N. B.—The temperature at the bottom is 81° C. (178° F.).	
In Spain, the boring having been made for oil or natural gas	5,285 ft.
At Schladenbach near Leipzig, Germany	5,735 ft.
At Leipzig	6,265 ft.

(18)	World's Second Deepest Working Mine -the Village Deep Shaft in the famous Rand Mines near Johannesburg, South Africa	7,630 ft.

Note.—So extensive are the operations in this deep mine that they often cause rock-slips similar to light earthquakes and felt repeatedly in Johannesburg. The temperature at the bottom is 36° C. (97° F.). Four tons of ice are used daily to make the lot of the miners at work bearable. In the mines of the Rand or Witwater's Rand is found the greatest concentration of gold known. The total quantity of gold taken out of them up to the end of 1931 is of the value of roughly 1 billion sterling.

(19)	World's Deepest Working Mine—the Morro Velho Gold Mine near Sabara in Minas Geraes State, Brazil	8,000 ft.= 1 m. 4 f. 27 yds.

Note.—The temperature at the bottom is over 49° C. (120° F.). The mine has been worked since 1725. Owing to its age, the production from it is decreasing.

Most of the world's gold is now extracted by quartz (silica) mining, and the undertaking requires vast amounts of capital. Other important gold mines in the world besides those already named are the Boliden in Northern Sweden, one of the newest and probably richest; the mines in Northern Ontario and Quebec, Canada, which are new; the mines in Alaska, California, Utah, Colorado and the Black Hills of South Dakota, all in U. S. A.; and those in Russia and Siberia. The output of the Canadian mines is a little less than one-fourth that of the Rand, and in 1931 amounted to 2,693,892 fine ounces valued at nearly 11½ million sterling. The Californian fields

have produced, since they started work in 1848, about 370 million sterling worth of gold. In 1931 they yielded half a million ounces worth over 2 million sterling. The output in Russia in 1931 is estimated at about a million ounces worth over 4 million sterling. The world's total output in 1931 was 21,300,000 ounces worth over 80 million sterling.

(20) World's Deepest Boring	10,030 ft.= 1 m. 7 f. 43 yds.

Note.—This record depth, says *Popular Science Monthly* of December 1931, has been reached in an Oil Well drilled near Seacliff in California. The shaft is officially known as 'C.C.M.O. Hobson 9-2'. Huge steel derricks, nearly 200 ft. high, were set up across the drilling platform, holding tremendous loads of drill pipe and casing weighing upwards of 100 tons, while Diesel engines and electric motors turned rotary drills with marvellous speed and smoothness. Bits faced with the hardest steel rotated furiously and burrowed into the hard rock. Pumps exerting enormous pressures drove in streams of liquid mud through 4 miles' length of pipe, and raised it to the surface again along with abrasive cuttings, while its circulation in the interior softened the walls of the hole. Circular rubber washers, moistened with water, spun round the revolving drill pipe, enabling the hole to maintain perfect verticality throughout. Hot formations in the interior were chilled by vast quantities of ice forced into the hole under pressure. When gas pressure fails, the oil is drawn from the depths by giant electric pumps of extraordinary lifting power. The new 'super-well' tapers to a diameter of only 5 inches at the extreme bottom. Geologists predict that with modern technique and machinery it will be possible to dig still deeper into the ribs of Mother Earth!

At great depths the heat is extreme. In borings it has been found that the temperature rises about 1° C. for every 100 ft. increase of depth. Subterranean temperatures, however, show variations at the same depths in different localities. Thus a well drilled in one part of the Californian oil-fields showed a temperature at 6,500 ft. of 210·3° F. (99·55° C.), very near the boiling point, but another recorded 206° F. (96·66° C.) at a depth of 7,800 ft. These fluctuations, according to some geologists, are probably due to folds in the structure of rock in the interior which surface mapping does not reveal.

(21) Depth at which the temperature would reach about 1,620° C., a point sufficient to melt any conceivable rock	54 km.= 33·75 miles

Note.—This item is based upon Jeffreys' estimate that the earth's internal heat increases with depth at the rate of about 30° C. per km. The melting points of rocks vary, the highest being that of Dunite, *viz.*, 1,500°-1,600° C. Besides at least 12 metals (which include platinum and uranium) there are two forms of silica, a few silicates, some of the hardest minerals and the artificial corundum or crystalline alumina which do not fuse even at 1,620° C.

(22) Depth at which the Earth's internal heat would reach 3,000° C. } 100 km.= 62·5 miles (*Jeffreys*)

Note.—Once this temperature is reached, says Jeffreys, a uniform heat is maintained in the earth's lower depths. The inference is that 3,000° C. would be the highest temperature occurring anywhere in the earth's interior. This is a temperature which, it may be of interest to note, is more than sufficient to melt all known substances with but two exceptions, *viz.*, the rare metals rhenium and tungsten. Rhenium or Dvi-manganese is an element of which only spectra have been obtained, and it is said to exist in infinitesimal quantities in manganese salts. Its melting point is given as 3,150° C. Tungsten, the metal used in filaments of electric light bulbs, is derived chiefly from the compound wolfram, a tungstate of iron and manganese, and in smaller quantities from scheelite or calcium tungstate. It is the most refractory substance known, and under standard conditions melts at 3,381° C.

The highest temperature yet attained artificially is 3,600° C., which was recently reached in an experimental electric furnace called the inductor or high-frequency furnace invented by Dr. E. F. Northrup of Princeton, U.S.A. In this furnace graphite, familiarly known as blacklead, the mineral used in making pencils, has been turned into vapour!

(23) Distance from the surface of the Crust to the Earth's Centre } 3,963·5 miles

Note.—One may wonder what the pressure may be at the centre of the earth. The pressure below the surface of the crust naturally increases with depth, and at the earth's centre, according to Dr. Abbot, Director of the Smithsonian Astrophysical Observatory at Mt. Wilson, U. S. A., is something like 50 million lbs. (about 22,320 tons) per square inch, which is equivalent to 3,400,000 atmospheres!

(24) Distance from the Earth's surface to the extreme bottom of its Central Core } 4,022 miles approximately

Note.—The central core is believed to be composed of super-heated metallic iron or nickel-iron alloy. Jeffreys remarks that evidence has shown that its radius is 'rather more than half of the earth as a whole.' Another authority considers that the core is 3,500 km. (2,187·5 miles) thick, as will be seen presently.

Some geologists classify the earth's crust into Sedimentary Layer, Granitic Layer, Tachylyte Layer and Dunite Layer, according apparently to the regions or depths where the corresponding rocks were originally formed. They also give their estimates of the probable thickness of each layer and of the central core, along with their relative densities. The thickness and densities of the different layers and the core, along a radius drawn from a typical point on the surface of a continent, are given in the *Encycl. Brit.*, 1929 as follows:—

	Thickness in kilometres	Density
Sedimentary Layer	0-5 (?)	2-2·7
Granitic Layer	10	2·7
Tachylyte or Diorite Layer	20	2·9
Dunite Shell (possibly with Eclogite near the top)	2,900	3·3 (top) 5·0 (bottom)
Liquid Iron Core (as the *Encycl.* refers to the Central Core)	3,500	11-12
	6,435 km.=4,022 miles.	

Jeffreys and other authorities often refer to the first two layers as the Upper Layer or Layers and to the third as the Intermediate Layer. The fourth layer, as to the composition of which there is difference of opinion, is variously described as the Dunite Layer, or Peridotite Layer or Eclogite Layer. The thickness of the core is roughly calculated on the basis that seismological observations have revealed that its radius is about 0·55 per cent of the outer radius. Geometrically described, it would be an eccentric sphere within our globe.

Concluding Remarks

The probable condition of the earth's interior has from time to time been closely investigated by geologists, physicists, mathematicians and astronomers from their respective view-points, but no definite conclusions which can meet all objections appear to have been reached yet. 'The problem of the physics of the earth's interior', remarks Jeffreys, 'is to make physical inferences only for a range of 2 kilometres at the outside.'

In the earliest life of the earth when it was very hot and entirely fluid, the materials of which it was composed, *viz.*, iron and silicates, would not mix but would separate and settle according to their relative densities, so that the denser constituents would sink towards the centre, leaving the lighter ones outside, *i.e.*, above. In cooling and hardening, the earliest formed portions of the crust would naturally descend until they reached a stratum having a density equal to their own, and this process went on repeating itself until the layers of lighter materials solidified and hardened.

The main difference of view among geologists is regarding the physical state of the last layer of rock and of the central core. It

will have been noticed from Item 22 that at a depth of 62½ miles the internal heat is 3,000° C., *i.e.*, far above the melting point of any conceivable rock. Once this temperature is reached in the earth's interior, explains Jeffreys, a uniform heat is maintained, in its lower depths as when a temperature is attained which is sufficient to fuse all substances, a general equilibrium is brought about. In his view, below a depth of 250 miles, the strength of the crust would probably be absent after the transition of the last layer of rock from a state of firmness and strength to one of gradually increasing liquidity. These transitional stages would thus include those of flexibility or plasticity and then of viscosity. One of the arguments advanced by those geologists who are in favour of the theory that the rock material after a certain depth must be existing in a liquid state, is that volcanoes erupting torrents of lava must be supplied from an immense molten nucleus or magmatic reservoir. In their view, again, the existence of only a thin and somewhat flexible crust would satisfactorily account for the earthquake shocks which sometimes affect large areas of the globe.

According to other authorities, the melting point of rock is not reached until after a depth of 375 miles. The melting point of Dunite, a rock believed to be present also in the core of the crust, being 1,500° C–1,600° C. and of pure iron 1,535° C., they infer that the temperature of the material of the central core may be lower by some hundreds of degrees owing to the presence of impurities. They do not conceive of a temperature exceeding the melting point of rock existing anywhere in the interior. On the contrary, their conclusions would point to a diminution of heat after the last layer. Again, they contend that pressure would raise the melting point of rock but would lower, at least at low pressures, that of iron. Accordingly they expect that the central core would be more fusible than the surrounding rock, and if the latter is near its melting point, the iron must be liquid. They state further that seismological evidence proves the solidity of the earth to nearly 2,930 km. (=1,830 miles), the depth at which the last layer of rock ends. In other words, all the rock material of the earth must, for the reasons mentioned, be existing in a solid state. These inferences are said to apply mainly to conditions below the land surface. The temperature at any depth in the crust is made up of two parts, one arising

from the original heat and the other due to that developed by radio-activity since the solidification, and as radio-activity below the seas must be less, the cooling at great suboceanic depths may be up to 30 per cent or higher.

The theory of solidity of the rock material throughout would not preclude a satisfactory explanation as to the source of the vast quantities of lava ejected by volcanoes, as there may be comparatively small accumulations of molten rock here and there, or what is even more probable, some temporary relief of pressure may lower the melting point and allow the rock to liquefy.

Yet another theory about the physical state of the earth's interior is that except for loca lvesicular spaces or cavities our globe is practically solid and rigid to the centre. Some scientists consider that the interior is gaseous, others that the substratum is probably very hot and dense and, though subjected to great pressures, cannot be described as either solid or liquid or gaseous in the popular acteptation of these terms, but that if it is liquid or gaseous, the material is so confined and compressed that it acts very much like a solid.

According to Professor H. H. Sheldom of Newport University, if the earth's interior were a freely flowing liquid, a temperature throughout of 3,000° C. would probably be present. Conversely, therefore, if so high a temperature exists below a depth of 62½ miles, it would probably be sufficient to reduce the interior gradually, somewhere below that level, to the state of a freely flowing liquid. But whatever be the temperature in the interior, he concludes, experiment shows as a fact that the elasticity of the material in the depths of the earth would be about that of rigid steel, and owing to the enormous pressure and density it probably behaves much like a solid. The majority of geologists now consider, on physical and astronomical grounds, that the earth's central core is solid, so that the old theory that it must be a 'Sea of Liquid Fire' has now few supporters.

Earthquakes are aptly described as convulsions of Nature. They are manifestations of the same underground forces as originate volcanoes, and are generally most common and severest in volcanic areas. They often precede or accompany violent volcanic outbursts. It is now believed by geophysicists that earthquakes are due to the sudden slipping or fracture of a part of the earth's crust which has

been subjected by slow earth movements to an undue strain. This view is largely based on their occurrence along coasts, mountain ranges and generally in areas where the warping of the crust is greatest. Strong vibrations are set up at the fractured surface at the time of the fracture, and these travel through the elastic solid material of the earth as longitudinal and transversal waves having velocities of 7 km. and 4 km. respectively per second. An earthquake sends out also a third class of waves over the earth's surface known as Rayleigh waves whose speed is 3 km. a second. The region on the earth's surface which is immediately above the earthquake origin or focus and to which the shock is delivered vertically upwards is known as the *epicentral tract*. These three types of waves sent out by the earthquake are recorded at the seismological observatories all over the world by a class of instruments known as *seismographs*. Modern seismographs are so sensitive that they are capable of recording these waves even if the earthquake occurs at the antipodes. For instance, the shock of the earthquake which occurred in Chile, South America, on 2nd December 1928, and of the one in Mexico on 3rd June 1932, caused violent oscillations in the seismographs at the Colaba Observatory, Bombay, which is situated very near the antipodes of the epicentre. Owing to the different velocities of the three waves they arrive at a station at different times, and by noting this difference in the time of their arrival, seismologists calculate the distance of the epicentre. By a system of triangulation between three or more seismological observatories the exact position of the epicentre is determined and broadcast to the public long before information arrives from the place or places seriously affected by the earthquake. It may be emphasized that the surface waves are considerably more violent than the other two waves which travel through the interior of the earth's crust. The destruction of buildings and bridges and sometimes of whole villages or towns caused by earthquakes is due mainly to the surface waves.

There are definite regions on the earth which are frequently liable to earthquake shocks, and there are also areas which are more or less exempt from them. The former regions constitute definite belts over the earth and are known as earthquake zones. Geologists describe such areas as *fault-lines*. For example, the Khasia Hills in Assam, the mountain ranges in the north-west of India and the

submarine region near the Andaman Islands are well-known earthquake zones. It has been found that submarine earthquakes set the ocean waters in motion and give rise to great water waves. These waves occasionally travel from one side of the ocean to the other. (*Vide* description of the Krakatoa eruption in 1883 under Chapter IV).

Dr. G. W. Walker, Director of Eskdalemuir Observatory in Scotland, in 1921 made the startling suggestion that the depth of the earthquake focus is of the order of one-fifth of the earth's radius or about 1,250 km. The late Professor H. H. Turner of the University Observatory at Oxford estimated the depths of the focus of some earthquakes to be of the order of 300 miles. Dr. S. K. Banerji, Director of the Colaba and Alibag Observatories, in a paper published in the *Philosophical Magazine*, Vol. XLIX, January 1925, questions Turner's estimate and by an analysis of recorded results concludes that the maximum depth must be less than 200 km. but may be anything in the neighbourhood of 100 km. Subsequent writings of Dr. Jeffreys, Dr. C. G. Knot and others generally confirm the results obtained by Banerji. It is now generally accepted that the earthquake focus normally lies between the surface of the crust and a depth of 100 km.

Many observers have recorded a curious sound at the occurrence of an earthquake. In the neighbourhood of the epicentral tract the earth's crust abruptly undergoes violent changes owing to the passage of the surface waves. These have been found to give rise to vibrations in the air resembling a rumbling sound like that of distant thunder.

As a rule, the more intense the shock, the larger is the area affected by an earthquake. An earthquake which occurred in Chile, South America, in 1835 was felt over an area estimated at 600,000 sq. miles. Earthquakes are sometimes so severe as to cause huge loss of life apart from the havoc to property. At a severe earthquake in 1905 in the Kangra District of the Punjab no fewer than 20,000 persons perished. The geological effects of earthquakes are chiefly the local elevation and depression of land, and the opening of rents in the ground. In the earthquake of 1822 in Chile the coast-line was raised about 4 feet. In India an earthquake which occurred in the same year in the State of Cutch depressed a large area all at

once below sea level. At the earthquake in New Zealand in 1855 an area of about 5,000 sq. miles was elevated about 9 feet, and a crack, 6 to 9 feet wide, formed along the margin of the raised ground for a distance exceeding 90 miles.

Weird subterranean sounds not connected with the earthquake are sometimes produced by other agencies. In the Chilean Andes a hollow sound booms at times from Mt. El Bromados, which is consequently known as the 'moaning mountain'. There is a remarkable mountain in Nevada, U. S. A., which gives out sounds 'resembling at first the jingling of bells and ending with a deep organ-like swell'. Mt. Cross Fell, a peak which borders Westmorland and four other counties of England, is given to howling so dismally that for a long time the inhabitants of the surrounding districts looked upon it with superstitious dread. Sometimes during a strong gale it sends forth 'an awe-inspiring scream' audible for miles around. Such sounds are either of volcanic origin or due to the crust movement produced in particular kinds of soil by the sudden loss of heat on account of intense radiation during exceptionally clear nights. Particular soils may give rise to particular sounds.

A curious effect of subterranean disturbances on the waters of a lake was reported in the Press by a correspondent from Naples on 9th November 1931. In Lake Carpena, 30 miles away from the famous volcano of Vesuvius, the water was found to sink several times daily, leaving the bed exposed, and then with underground rumblings and local earth tremors, gush up rapidly, boiling-hot, to its original level. The return of the water was at all times preceded by a dense fog which lifted as soon as the lake became full again.

Those who hold that the earth's deeper interior consists of molten material call the solid outer crust the Lithosphere. The earth's oceanic area is called the Hydrosphere, its gaseous envelope the Atmosphere, and the mass of living organisms on the earth is sometimes termed the Biosphere.

What may be the weight of the load which, in Hindu mythology, Mahāpadma and other elephants are said to sustain, or which, according to Lamaistic belief, is borne on its back by a gigantic frog? Science has already answered the question, for the earth has been 'put into the scales'! Its mass was ascertained by comparing the

strength of its gravitational pull on a small sphere at its surface with the attraction exerted on this body by a big sphere whose mass was known. The force of attraction is in accordance with the law of gravity, which is that the pull on a small body is proportional to the mass of the attracting body divided by the square of the latter's radius, this radius denoting the distance of its centre. From the amounts of the forces produced and the distances, the ratio of the masses was obtained. In this way Professor C. V. Boys, a British scientist, got the necessary data and announced some years ago the weight of the earth as 5·885 sextillion tons. The German scientist, Dr. Braun, working independently, arrived at very nearly the same result. These values are a little lower than that declared more recently by Dr. Paul Heyl of the American Bureau of Standards, an institution which seeks the greatest possible accuracy. By working in an underground chamber where he could more effectively shut out street noises and other disturbances—for the slightest vibrations produced by passing vehicles would seriously interfere with the proper working of the highly delicate and sensitive instruments used for the purpose—Heyl has worked out the weight of our globe as 6·593 sextillion tons, only about 12 per cent higher than the British Professor's estimate. Among other authorities Dr. Baker, Professor of Astronomy at Illinois University, accepts the higher value.

One may wonder to what use a knowledge of the earth's weight can be put. The astronomer would answer that it furnishes the starting point from which to calculate the weights of heavenly bodies.

CHAPTER II

The Hydrosphere or Ocean

Thou glorious mirror, where th' Almighty's form
Glasses itself in tempests; in all time,
Calm or convulsed—in breeze, or gale, or storm,
Icing the pole, or in the torrid clime
Dark-heaving;—boundless, endless, and sublime—
The image of Eternity—the throne
Of the Invisible; even from out thy slime
The monsters of the deep are made: each zone
Obeys thee: thou goest forth, dread, fathomless, alone.

—*Byron*

It will have been noticed from the preceding chapter that the 'Fires of Hell' are present within our Earth itself, whether its core be solid or liquid. We now turn our attention to the earth's enormous body of water, its liquid envelope. But before starting our investigation of the ocean's interior, let us see if there are any phenomena above its surface which merit notice.

(1)	Height which a Sea Fog has been found to reach	About 2,500 ft. (*Negretti & Zambra*)

Note.—Sometimes the fog appears in massed stretches resting upon the sea and resembling distant land, but vanishing as it is approached. It is then called a Fog Bank. Fog Banks are sometimes arranged in a circular form and are then called Fog Rings. They are often seen off the coast of Newfoundland. Long dreaded by mariners, they are now feared by trans-oceanic aviators.

(2)	Usual Height of a Sea Fog	About 700 ft. (*Negretti & Zambra*)
(3)	Height of a Waterspout	200-350 ft. (*Negretti & Zambra*)

Note.— A waterspout is a remarkable phenomenon of the nature of a tornado or whirlwind, witnessed frequently only in parts of the tropical seas when the sky is overcast with massive clouds and the atmosphere is tense with electrical energy. Its occurrence is due to a meeting of opposite winds of different temperatures in the upper air, whereby a large quantity of vapour is condensed into a dense

cloud which, descending in a dark column resembling the trunk of an elephant, moves along, sometimes in a straight and vertical, at other times in an inclined and tortuous direction. This motion results in the formation of a huge funnel which, coming down near the sea surface, violently agitates the water and sucks it up, sometimes in large quantity. The entire column—sometimes several at a time each 20 to 30 ft. in diameter—then seems to extend from the sea to the clouds, taking a magnificent form of a light colour near its axis, but dark along the sides, and moving along in rapid gyration. When acted on by the wind, the column assumes a slanting position, but in calm weather it remains vertical while continuing its motion. Sometimes the upper and lower parts move with different velocities and break away from each other with a loud report. The whole of the vapour is at length absorbed in the air, or it comes down in a heavy shower of rain.

The extraordinary phenomenon of six waterspouts operating in circular formation has once been observed during a storm in the Sulu Archipelago, between Sandakan, British North Borneo, and Sitangkai. In the Atlantic, west of Africa, spouts sometimes appear in the months of June and December in large numbers, like forests of trees planted in the ocean.

The waterspout, in ancient times, was variously accounted for. Primitive races imagined it to be a gigantic sea-monster marching across the ocean. The Japanese believed it to be a dragon with a long tail. Among the Chinese it was a dragon coming down from the sky to drink water. The Hindus believed it to be Airāvata, the elephant of the storm-god Indra, alighting on the sea to slake its thirst. The Mahomedans believed it to be a huge demon rising from the sea like a black pillar and going up into the sky.

A writer in *Star* expresses the view, which he says is based on close and repeated observations made by him of this phenomenon in its various stages, that none of the water content of a spout is obtained by suction from the sea. When what aviators call an 'air pocket' is not filled up slowly to the level of the surrounding atmosphere, it assumes under certain conditions a circular motion and this centripetal movement, should there be any dense superimposed clouds in the vicinity, sucks up from them the water-vapour which condenses on the wall of the cone down to the apex in a swirl

and thus leads to the formation of a waterspout. In support of his theory the writer states that the water in a spout has always been found to be fresh.

Waterspouts are not confined to the seas alone. They occur on land too, but the land phenomena are usually called cloudbursts or tornadoes. Some tornadoes are dry whirlwind hurricanes, though in appearance and action they do not differ from cloudbursts. In 1930 an unusually violent tornado swept over Nebraska, U. S. A. After a furious rotation down from the clouds its black twisting funnel rushed to the earth, struck a pond and, according to the report, sucked it dry! This incident affords strong grounds for the belief that, as on land, so at sea the spout must derive its water content by absorption from the body of water below. But if the *Star* correspondent's assertion that the water in a spout is always fresh is correct, it can only mean that a spout acts differently at sea. Meteorologists can no doubt throw light on this point.

A huge waterspout was witnessed on the great river Brahmaputra at Mymensingh (Bengal) on 19th September 1931. It was described as an unprecedented phenomenon in India. It occurred in the morning when the spout was seen suddenly to raise itself out of a depression which formed in the centre of the river. A mighty column of water soared into the sky and after keeping hundreds of people awe-stricken for about 20 minutes, the spout collapsed with a roar, breaking into two parts and falling in twin cascades of water. A boat which happened to be in the vicinity narrowly escaped being engulfed as the water descended to the river.

(4) Usual Height above water of the highest of Icebergs	100 metres = 328 ft. (*Encycl. Br., 1929*)

Note.—The land in polar regions is buried under an enormous ice-sheet, which is continually moving seaward from the central ice plateaux and frequently comes to the sea before reaching a temperature sufficient to melt it. Mighty fragments of ice thus become detached from the edge of the main sheet and float away as *icebergs*. They assume an endless variety of shape, often irregular and fantastic. Icebergs exceeding 100 metres in height are extremely rare. The largest bergs in the northern seas are sometimes 2 miles long and about a mile in breadth. Hundreds of such a size have once been counted as they drifted along between Lat. 60° and 70° N. An unusually huge iceberg, 2·5 miles long, 2·2 miles broad and 153 ft. high, has once been observed in this region, and its weight was estimated at about a

billion and a half tons. Of all forms of ice in the sea, the iceberg is the most spectacular and at the same time most dangerous to shipping.

(5)	Height to which Billows dashing against a cliff have been found to hurl up sheets of water and foam at a gale	Over 300 ft. (*Encycl. Br., 1889*)

Note.—At Dunnet Head (Scotland), during north-westerly gales, the window-panes of the lighthouse which stands more than 300 ft. above the high-water mark are sometimes broken by stones swept up the cliffs by the billows, and the building is then deluged by sheets of water rushing in through the windows.

(6)	Height to which Billows dashing against a cliff have been found to throw up sheets of water and foam when no wind is blowing	Nearly 200 ft. (*Encycl. Br., 1889*)

Note.—This occurs on rare occasions on the northern coast of Scotland.

(7)	Height which Waves have been found to reach in abnormal weather	Over 70 ft.

Note.—Waves have been seen on one occasion which reached this height in the North Atlantic during a prolonged storm. On 29th December 1922 the wind in this region attained and kept up for a considerable time a hurricane velocity computed to have been 75 miles or more an hour. Observations showed that the waves then reached a height of upwards of 70 ft. from trough to crest. It has been found that the height of waves in the open sea varies directly with the velocity of the wind. On only one occasion in the world's known history has even this height been exceeded. (See the description of the eruption of Krakatoa under Chapter IV).

(8)	Depth to which the thickest of Ice-Floes may be under water	About 14 ft.

Note.—Ice in the frigid zones occurs in a variety of forms. A *floe* is a low flat mass of drifting ice of considerable size, but with visible limits. When the sheet of ice is so large that its extent is not discernible from the mast-head of a ship, it is called an *ice-field*. Oftentimes huge masses of drifting ice are packed together in large numbers and form what is called *pack-ice*. As in the case of an ice-field, its limits cannot be seen. Ice-packs occur in two forms—'open' and 'close'. When the assembled masses of ice, though floating very close to one another, do not touch, the pack is said to be 'open'; when they are in actual contact, it is said to be 'close'. Pack-ice covers nearly 2 million square miles and constitutes about 70 per cent of the Polar Basin. Ice-floes and ice-fields usually become covered with snow to a depth which presses down their surfaces to the level of the sea.* The greatest thickness attained by them is about 14 ft. When the cold is extreme, floes undergo

contraction in which process they frequently break up with a rending crash known as the *ice-quake*. Sometimes pressure due to winds and currents raises ridges upon an ice-field, which may attain a height of as much as 50 ft. above the sea level. These lofty piles are called *hummocks*. Along the shores in the Arctic regions runs a fringe of ice. This is called an *ice-belt*. Another form in which ice appears in the frigid zones is the *iceberg*, though bergs sometimes drift along towards the equator to latitudes as low as 40^0 N. or S.

A curious phenomenon due to the existence of ice-fields in the polar seas is the *ice-blink*. It is a bright yellowish-white streak observed on the horizon owing to reflection of light from the snow-covered surface of the ice and is seen before the icy mass itself becomes visible. As the poet, James Montgomery, describes it :—

'O'er rocks, seas, islands, promontories spread,
The Ice-Blink rears its undulating head,
On which the sun, beyond th' horizon shrined,
Hath left his richest garniture behind.'

(9) Depths at which under-water operations in the majority of Harbour, Dock, Quay and Bridge Works are carried out ... 40-80 ft.

Note.—The divers go down in a caisson or in a diving suit. A caisson is a strong water-tight case employed in building the foundations of piers and bridges under water. A diving suit is a waterproof costume of strong material worn by a diver when descending into and working under water. It has a metal helmet provided with strong glass eyes. The diver goes down with heavy leaden weights fastened to his sides and his shoes also weighted, so that he may descend and move about below with perfect ease. In both contrivances air is supplied through a flexible tube connecting the caisson or the head-piece with air-pumping apparatus above. Caisson workers and divers using diving dress are liable to be affected by morbid changes known as caisson disease as an indirect result of exposure to abnormal pressures under water. The limit of depth to which the caisson can be utilized is about 100 ft., and the men work only two hours a day, even this short period being divided into two one-hour shifts with an interval of four hours in between.

(10) Depths at which Pearl Divers work ... 24-120 ft.

Note.—Pearl oysters live at these depths, though they are mostly collected at 42–48 ft. In Arabia the divers go down 90 ft. to collect them, while pearl-fisheries in Australia are usually carried out at a depth of about 120 ft.

(11) Record Depth to which a Sea-bird has been found to dive in search or pursuit of prey ... 120 ft.

Note.—It is the cormorant (sea-raven or sea-crow), a large, natatorial, web-footed bird of the pelican family, the largest measuring about 33 inches

from head to wing-tip. It breeds generally on steep cliffs near the sea and sometimes on trees. It devours fish with such voracity that it has come to be regarded as the emblem of gluttony. When it sights prey, it vigorously pursues it by swimming and diving, descending often to a remarkable depth. A cormorant has been caught in a crab-pot fastened 120 ft. under water! At the base of the lower mandible it has a distensible appendage of naked skin which serves as a sac for temporary storage of its captures, and on rising to the surface it swallows them. When it has fed itself to excess or the tide is not favourable for fishing, it rests on an elevated perch, often with the wings outstretched, and remains motionless in this posture for a considerable time. A species of this bird is trained by the Chinese who find it very useful in fishing. A strap is tied round its neck so that, while it can breathe without difficulty, it cannot swallow its catches! It is then thrown off into water. It dives immediately and darts swiftly along the bed in quest of prey. So great is its activity under water that in a shallow river not a single fish can escape capture except by concealing itself under a rock or in the mud stirred up by the bird in its rapid movements.

Exactly similar in its habits is the pelican, a water-fowl larger than the swan, with an enormous bill, an expansible gular pouch and a great extent of wing. Like the cormorant it is an excellent swimmer and diver and catches fish with wonderful adroitness. It is to a large extent gregarious and frequents the sea-coast and the shallow borders of lakes and rivers where fishes are abundant, as it requires huge quantities of them for its sustenance. In India it may be seen in flocks on the banks of many rivers. In the Province of Sindh the pelican is sometimes used for capturing fish from the Indus river. The Sindhis put a ring round its neck to prevent it from swallowing its captures.

(12) Maximum Depth at which work is done by Sponge Divers in the Mediterranean Sea } 150 ft.

Note.—Sponges are a class of marine animals with a fibrous framework, soft, light and porous, which is remarkable for its compressibility and power of sucking up water. They are found fixed to rocks, or in the mud, or upon sea-weeds or on the bodies of other sea animals.

The pressure in the ocean increases with the depth. As a diver descends deeper and deeper, his ears ring with strange noises and he feels a crushing weight pressing on his head and chest. Pearl and sponge divers make a short stay at the bottom and thus generally avoid pressure troubles. The effect of pressure in the interior of the sea is easily tested. If we take an empty bottle, cork it, attach a weight to it and let it down by a line into the sea depths, we shall find on pulling it up that the cork is driven into the bottle and the bottle

filled with water. If we repeat the experiment with a hollow glass ball, either the ball will be crushed or the pressure will force water into it through microscopic holes in the glass.

The pressure exerted at any given depth in the sea is worked out by a simple calculation. At sea level the air pressure is about 14·7 lbs. to the square inch, and this unit is called *1 atmosphere.* The rate of increase of pressure in the ocean is 1 atmosphere for every 33½ ft. of depth. Thus the pressure at 33½ ft. will be *2 atmospheres,* at 67 ft. *3 atmospheres,* and so on. At 150 ft. the pressure will thus be nearly 5½ atmospheres. The common method of calculating the pressure at great depths is first to multiply the value of the depth in terms of a mile by the average density of sea-water, which is about 1·035. The product represents the approximate pressure in tons.

Until a few years ago a diver could go down in the ordinary diving suit to only about 120 ft. He had to descend slowly so as to take not less than a minute and a half to reach this depth, and he could work under the sea for nearly an hour. It may be explained that the increased air pressure to which a diver is subjected as he goes down is immediately transmitted to all the internal parts of his body. Of the air which he breathes, the oxygen is consumed by the tissues, and his act of breathing prevents any increase in the pressure exerted by the carbonic acid gas, but at considerable depths an abnormal amount of nitrogen is forced into his blood. A diver using the old apparatus had to ascend by slow stages, taking an hour and a half to reach the surface so as to allow the escape of the excess of nitrogen from his blood. A too rapid ascent would cause the nitrogen to form small bubbles and produce compressed-air illness such as paralysis of the legs, violent pain in the joints and muscles, vomiting, fainting and sometimes even death. It is now possible for a diver using the old diving suit to avoid the long ascent by means of a specially devised apparatus. This is a submersible decompression chamber, which is sent down by a crane from the diving ship, with an attendant, a supply of oxygen bottles, tea and coffee in thermos flasks and other necessities within it, to meet the diver below. The bottom of the chamber is opened and the water kept out by pressure. The diver enters this chamber from beneath, and the trap-door is closed. The pressure inside is the same as

that at which he has been working. The chamber is then hauled up and placed on board the ship, which returns to the harbour. The diver remains in the chamber throughout, and the pressure inside is steadily lowered until it becomes equal to the pressure of the air outside. The top is then opened, and the diver and the attendant come out. The whole process of decompression and return to normal pressure takes half an hour or less.

There is, besides, another important and useful invention which now comes to the diver's aid. It is the 'recompression chamber' or 'diver's hospital', and is kept on the deck of the ship. If by any miscalculation of pressure, the diver is allowed to step out into the air before he is fully 'decompressed', he is instantly seized with severe pain. In such cases he is immediately placed in the recompression chamber, the pressure is brought up to the point at which he was working under water, and he is subjected to gradual decompression.

It has been found from experiments that helium gas prevents caisson disease in divers owing to its low solubility in the fluids of the body. In U. S. A., which owns fields of natural helium gas and commands practically the world's entire supply, a mixture of oxygen and helium is nowadays used in deep diving and caisson operations instead of air.

The world's record for the longest period spent by a diver continuously under water appears to be 5 hours, 40 minutes. Attempts are in progress in Portland, West Bay, U. S. A., towards salving the sunken Submarine Boat 'M2' which lies at a depth of 100 ft. Expert deep-sea divers of the American Navy have spent a total number of 247 diving hours between 5th March and 30th May 1932 in these efforts, and one of them established the above astonishing record.

Italy possesses the biggest Divers' School in the world. It is situated at Spezia, her naval base. The final examination consists of tests of the diver's ability to work for two hours at a depth of 125 ft. in a diving suit weighing 165 lbs. and lead-soled boots each weighing 15 lbs. The Italian diver carries a weight of 38 lbs. on his back and another on his chest. At the school he is taught to work with under-water tools and receives instruction in the thrilling feat of fighting sharks and huge octopuses with no other weapon

than a knife. A fight with such ferocious animals at a depth of 125 ft. calls for considerable skill, as the diver's arms are greatly hampered by a pressure of nearly 5 atmosphers, while his foes, being in their natural element, are able to move adroitly and swiftly.

(13) Greatest Depth at which work has been done by Divers descending in diving dress } 275 ft.

Note.—This work was accomplished at the salvage of the American Submarine 'F 4' sunk off Honolulu. The equipment used by the divers was the British Admiralty Decompression System. The pressure at the bottom here would be 9 atmospheres.

A flexible and more comfortable dress, which is at the same time safer from the point of view of the diver's health, is that invented many years ago by the German engineers, Neufeldt and Kuhnke. It is made of cast steel cylinders. It permits the diver to explore the ocean freely up to a depth of 240 ft. This dress was used by a diver who worked at this depth on the wreck of the Belgian steamer 'Elizabethville' sunk in 1917 off Belle Isle.

(14) Depths at which Reef-building Coral Polyps and Nullipores ordinarily flourish } 25–300 ft.

Note.—Coral is composed of the hard calcareous skeletons or framework of various marine organisms called zoophytes. Coral structures are sometimes found at very great depths. In such cases the sea-bed must have been gradually sinking, while the coral polyp, operating near the surface, built the bank higher and higher as the bed sank. In other cases, these formations project well above the surface owing to the slow rise of the sea-bed. The most precious coral beds are found in abundance in shallower waters, *i.e.*, at depths of 25 to 50 ft. Coral structures sometimes, as in the Pacific and southern parts of the Indian Ocean, grow up to extensive reefs stretching along the coasts.

Besides the coral polyps the most important reef-builders are the nullipores, a kind of sea-weed having the appearance of coral. Of these two classes of reef-builders, the corals thrive up to a depth of 150 ft., and the nullipores up to 300 ft., in the warmer seas. The Great Barrier Reef of north-eastern Australia is the largest of its kind in the world. It extends along the coast for about 1,035 miles, being separated from the continent by a lagoon, 20 to 70 miles wide, containing a number of small and large islands. On its oceanic side the Reef rises perpendicular from a depth of nearly 12,000 ft.

Coral reefs sometimes appear as islands known as *atolls*. In some cases they present an exceedingly picturesque appearance—a narrow and nearly circular strip or ring of coral formation with a thin layer of soil covering its surface and a luxuriant growth of cocoanut palms, the odorous, fruit-bearing screw-pine and breadfruit trees, enclosing a lagoon of still water,

usually of considerable depth and often well stocked with fish. These circles of coral rock are sometimes complete, showing no communication anywhere between the surrounding sea and the inner lagoon, but as a rule they present one or more openings, frequently of sufficient width and depth to permit the passage of boats. The largest atolls are about 40 miles across. There is a small one in central Fiji named Vatu Vară, which has an elevation of 1,030 ft. On the slopes of the large island of Timor in the East Indian Archipelago there are many lofty reefs, the highest being almost atolls, with an elevation of nearly 4,000 ft. above the sea.

The atolls nearest to India are the Maldive Islands to the south-west. According to travellers' accounts, they form vast masses at least as large as the Alps in total extent.

(15) Greatest Depth reached by a Diver going down in an ordinary diving suit } 304 ft.

Note.—Frank Crilley, the chief gunner's mate in the U. S. Navy, *descended to this depth in 1915 to investigate the sunken American submarine referred to in Item 13 above.* The pressure at this depth would be *about 10* atmospheres.

An armoured diving suit has enabled a diver to go down to a considerably greater depth, viz., 525 ft., in Lake Walchensee, Bavaria, but a diving feat is naturally easier in a fresh-water lake, where the currents are not so strong as in the sea, the water is of a lower specific gravity and the pressures therefore are lower.

A special diving apparatus has recently been constructed by an Italian firm for salvage work. The steamer 'Egypt' sank in a collision off the coast of Brittany (France) in 1922, with a consignment of gold and silver worth over £ 1,000,000. She lies in 400 feet of water. This treasure is being recovered by the use of the new apparatus. Divers succeeded in penetrating into the treasure-room of the steamer in June 1932 by blowing up the ceiling of the strong-room with a chain of bombs put in position, and by the end of August over half a million sterling worth of treasure had been salved. The device adopted for the work is a kind of robot, a mechanical steel shell with jointed arms and legs, in which the diver descends, the apparatus being lowered by a wooden derrick from the salvage vessel operating above. This shell is fitted with massive glass windows capable of withstanding the pressure it will be subjected to, and the diver need not breathe compressed air. He inhales oxygen throughout at normal pressure, and is thus able to avoid the use of compressed air with its attendant evils and risks. The robot has telephone connection with the ship above. In the lower part of the apparatus are tanks into which the diver lets water by means of a valve when he wishes to go down and from which he expels the water by compressed air when he wants to rise. But the most important part of the contrivance which has contributed to its success is the movable arms ending in a kind of pincers, like a giant lobster's

claws, which are equipped with hammers and other mechanical appliances, all controlled by the man within the robot through water-tight connections.

(16)	Depth at which the Spectrum of Sea-water in tropical regions is devoid of colour, violet being the last ray to fade from the water	700 ft.

Note.—This disappearance of colour has the effect of rendering the blue water at great depths brilliant and clear. In the far northern latitudes, however, the water below this depth would probably be as black as night.

The blue colour of the sea is due partly to the reflection of the sky, but mainly to the scattering of light by the gas molecules in the sea-water.

(17)	Stretch of Water across the Pacific which has been found to be an invisible fence without oxygen, forming an effective barrier to sea life	From 300 ft. below the surface down to 1,000 ft.

Note.—This belt stretches east and west across the ocean and is 100 miles wide. It forms a fence separating the northern marine life from the southern.

(18)	Greatest Depth at which beds of precious Coral are sometimes found	Over 1,000 ft.
(19)	Greatest Depth reached by Divers by descending in a Steel Sphere	1,426 ft.

Note.—This record descent was made by two Americans, Dr. William Beebe, oceanographer, and Mr. Otis Barton, in the latter half of 1930 in a Diving Sphere, a chamber about 6 ft. in diameter and constructed of steel 1½ inches thick. It had portholes fitted with fused quartz glass 3 inches thick and weighed 2 tons. It was built to withstand a pressure of 652 lbs. to the square inch or a little over 44 atmospheres. The interior was kept at sea level pressure, and an oxygen supply was taken for use under water. Through the steel hawser which lowered the sphere into the water electric cables were connected to the sphere to provide current for the lamps inside the ball and to illuminate the submarine darkness outside. The two divers went down in the sphere, furnished with a powerful submarine camera. Telephonic communication with the barge operating above enabled them to send up messages from time to time. 15 descents were made in the open sea off the coast of Bermuda Islands (east of U. S. A.), and on one occasion the divers reached a depth of 1,426 ft. They stayed at this depth for half an hour, and the total period spent by them this time under water was about an hour and a half.

Among the marine life they observed during their descents were: the 'Spotted Ray of Bermuda', a huge fish rhomboidal in shape, with spotted body and fins and poisonous spines; luminous fishes; a silver hatchet fish with

violet lights; a huge black fish of a ravenous appetite, which pursues its luminous prey to the surface of the ocean at night and is therefore called the 'Eater of the Stars'; an 'Under-water Danger Signal', *i. e.*, a Sea Anemone expanding and waving its crown of tentacles, large in number, and lying in wait for unwary fishes. It sparkles like a bunch of gigantic cactus blossoms and shines with very bright colours. Curious creatures glowing with white, yellow and pink lights were subsequently dragged up in nets from great depths, and they fought and devoured each other till the end.

According to American engineers, a steel sphere can be built to go down with divers inside, without difficulty, to a depth of even half a mile.

Such is the romance of the deep related to us in *Popular Mechanics Magazine* of October 1930.

From another journal we learn that the two investigators who descended in this sphere found that close beneath the ocean surface the light was ordinary daylight, but as they went farther down, all the red and yellow colours of the spectrum of the water faded out entirely. The blue colour faded next, and there were now left only the violet rays at the farthest end of the spectrum where the wave-lengths of light are shortest. At depths of 700 ft. and over, the outside world of water still appeared to glow, though dimly, with these extreme, almost colourless violet rays. The explanation given by physicists is that this effect is due to the action, partly of minute suspended particles in the top layers of the water, and partly of the water molecules themselves which absorb the rays of the red and yellow end of the spectrum, but allow some of the violet rays to pass.

(20)	Depths at which the greatest variety of marine fauna is found	500–2,000 ft.
(21)	Depth of the Gulf Stream	600–2,100 ft.

Note.—It is the most famous of ocean currents. The warmer water of the equatorial region flows into the Gulf of Mexico, where the Gulf Stream proper takes its birth. It is deepest where it leaves the Gulf, and is here about 50 miles broad. Passing along the Straits of Florida, it flows off into the North Atlantic as the blue, swift-flowing 'river in the ocean', attaining sometimes a breadth of 100 miles. Continuing its course northward, it mingles with the Antilles current, from which it receives a further supply of heat. Off Newfoundland it meets the cold Labrador current of the Arctic region. The difference in temperature between the two currents is so marked that on one occasion a ship passing from one current to the other found a temperature of 34° at the bow and 56° at the stern at the same moment. Here, at all seasons, the mingling of the warm and cold air masses overlying the two currents produces the fog banks for which this part of the world is so notorious, and in spring and early summer icebergs form a menace to shipping. From off Newfoundland the Gulf Stream sweeps onward in a broad, sluggish, shallow current known as the Gulf Stream Drift.

(22) Approximate Depth to which the lower parts of the highest of Icebergs are under water } 2,625 ft.

Note.—The specific gravity of ice is 0·9175 and that of sea-water 1·035, so that only about a ninth of the total mass of an iceberg is above water and visible and the remainder lies below. In the case of an iceberg which is nearly uniform and cylindrical in shape, its depth below the surface of the sea will thus be about 8 times its height above the water. In the southern seas the icebergs are tabular in form and are immensely larger than those in the northern, measuring up to 30 miles in length.

Icebergs are agents in transporting vast masses of mud, loose gravel, pebbles and rock from the north polar regions towards the temperate ones. Some have been observed conveying cargoes weighing from 50,000 to 100,000 tons. As these masses float southward, their submerged portions slowly melt away owing to the increasing temperature of the sea-water until the bergs become top-heavy and capsize. Their load of earthy debris is in this way deposited on the floor of the ocean. Icebergs act as agents in the process of denudation of the sea-bed, carrying out their operations at depths sometimes exceeding 2,000 ft.

(23) Depths at which only the rarer forms of Fishes are known to thrive } 1,500-3,000 ft.

(24) Greatest Depth from which a Whale has been hoisted up } 3,000 ft.

Note.—Capt. P. E. Harne of the cable repair ship 'All America', while investigating the cause of interruptions in the service of the All America Cable Company's line off the coast of Colombia (South America), hoisted up a huge dead whale weighing about 90 tons. His theory, based on similar experiences elsewhere, is that the whale was taking food by scooping along the ocean bed. Digging too deep in quest of food, it must have picked up the cable and been strangled in turning over to disengage itself, for, when the monster was brought to the surface, 180 feet of cable were found coiled around its body. The presence of a whale at so great a depth, where the pressure would be about 1,332 lbs. to the square inch or 90 atmospheres, is explained by the fact that it is protected by a heavy coat of blubber which enables it to withstand such a pressure.

The whale inhabits the colder waters north and south, and is rarely seen in tropical latitudes. The Province of Colombia is crossed by the equator. The reason that a whale could be found in such a warm region of the ocean is that this animal, especially the species called the Sperm Whale, is a great wanderer. Marine animals wander about in vast numbers on account of variations in their food supply. The minute forms of life on which the sperm-whale subsists are plentiful only in summer. To obtain the huge quantities of food it requires, this animal, says Dr. Charles Townsend of the New York Aquarium, wanders to and back every year over routes 6,000 to

8,000 miles long, enjoying the summer in the Northern Hemisphere and migrating to the Southern Hemisphere for the southern summer!

(25)	Depths down to which Sea Plants have been found growing	3,000–3,600 ft.

Note.—Plants do not grow below the level which sunlight penetrates. The plant found at these depths is a cluster of 'Sea Lettuce'.

(26)	Average Depth of the Arctic Ocean ...	3,954 ft.
(27)	Record Depth from which Reef-building Corals have been dragged up	Over 4,200 ft.

Note.—Such corals have been dredged in the Ceram Sea, Dutch East Indies, from a depth exceeding 700 fathoms, 30 miles away from the nearest shore.

(28)	Depth at which a huge black fish called the 'Underwater Torch Bearer' has been found	4,800 ft.

Note.—It has a projecting tentacle on its head, which carries a 'Bull's Eye Lantern'—a glowing 'lamp', and this helpful appendage lights its way in pursuit of prey.

(29)	Depth at which 'Illuminated' White Fish have been found	5,280 ft.= 1 mile

Note.—The pressure here would be about 1 ton to the square inch or nearly 158 atmospheres.

(30)	Average Depth of the Antarctic Ocean	6,000 ft.
(31)	Depth from which Star Fish have been collected	7,560 ft.

Note.—These fish are so named from the shape of their body, which resembles a star. The body usually has 5 rays or arms, though the number may extend to 40 or more. This fish is also named Stellerid.

(32)	Depth of the World's Water if the whole land portion of the earth and the bed of the oceans were reduced to a uniform level	8,800 ft.
(33)	Average Depth of the total Oceanic Area of the earth	12,450 ft.= 2 m. 2 f. 190 yds.

Note.—The average elevation of the Earth's land surface is only about 1,440 ft.

(34)	Average Depth of the Atlantic Ocean	12,874 ft.
(35)	Average Depth of the Indian Ocean ...	13,002 ft.

(36) Depth at which Submarine Cables are laid in the North Atlantic } 1,650-13,200 ft.

Note.—At the bottom of the Atlantic, extending from Newfoundland to Ireland, a distance of nearly 2,000 miles, there exists a remarkable plateau known as the Telegraph Plateau. It is nearly 400 miles broad. It is upon this plateau that the cables are laid, its soft oozy surface providing an ideal cushion for the network. They were first laid in 1866.

(37) Average Depth of the Pacific Ocean ... 14,052 ft.

(38) Greatest Depth sounded in the Mediterranean Sea } 14,436 ft.

Note.—This 'trench' lies between Sicily and the Peloponnesus.

Up to 1920 deep-sea soundings used to be taken by what are known as the lead and wire systems, but since then a new instrument called the sonic depth finder is employed in all modern ships to sound great depths. This device is based on the principle that sound waves originating at the ocean surface pass through the water at a known or ascertainable speed, and after striking the bottom are reflected or echoed back to the surface. The interval of time between the emission of the sound and its return is measured with accuracy. The velocity of sound in sea-water increases with the temperature, with the salinity and with the pressure, and varies from about 4,600 to 5,300 ft. a second. The sonic depth finder automatically records the time taken by the sound to travel to and back, correct to the split second. The time required to take a deep-sea sounding with the new device is almost negligible, and a depth of 24,000 ft. is sounded in about 10 seconds. Besides, soundings can be made at very frequent intervals and even while the ship is in motion, sailing at 10 to 15 knots. A still further advantage of the new method is that the instrument can be used in all weather conditions. The science of sounding water depths is known as bathymetry.

(39) Greatest Depth from which Vertebrate Fish have been dragged up } 16,500 ft. = 3 m. 1 f.

Note.—Fish with very large eyes named Bathylagus have been obtained from this depth, where the pressure would be about 3½ tons to the square inch or 493 atmospheres.

(40) Greatest Depth sounded in the Indian Ocean } Over 21,000 ft.

Note.—A Dutch submarine in 1924 measured, by the echo sounding method, depths exceeding 21,000 ft. north-east of Christmas Island situated south of Sunda Strait. There are parts of the Arabian Sea of immense depth, but only a few soundings have so far been taken, away from steamship routes.

(41) Deepest Sounding made in the Arctic Ocean } 23,100 ft. = 4 m. 3 f.

(42) Greatest Depth from which Sponges and Molluscs have been dredged up } Over 24,000 ft.

Note.—Molluscs are a large division of invertebrate marine animals, which includes the Cephalopoda, Sea-snail, Sea-slug etc. The highest in organization and generally largest class of molluscs are the Cephalopoda or Cuttle-fish group under which comes the Octopus or eight-armed Devil-fish noted for its ferocity. No particulars are available as to what particular genera of molluscs were obtained from the immense depth mentioned above or whether they included any species of the Cuttle-fish family. There is however a reliable record of the octopus having been taken from 11,250 ft. and of the *Eledonella*, a genus related to the octopus, from 17,400 ft., a depth at which the pressure would be 500 atmospheres. We learn from *The Sphere* of 2nd April 1932 that one record specimen of the octopus, *Cephalopterus Vampyrus* of the American coast, caught in Delaware Bay, measured 17½ ft. long and 18 ft. across and weighed 5 tons!

The pressure at a depth of 4½ miles at which animal life has been found to exist would be about 4¾ tons to the square inch or 725 atmospheres!

(43) Greatest Depth sounded in the North Atlantic } 27,972 ft.= 5 m. 2 f. 84 yds.

Note.—This depth has been discovered in the famous Nares Deep, a mammoth trough or 'hole' in the North Atlantic, lying about 50 miles north of the island of Porto Rico, West Indies, and extending about 180 miles east to west with an average breadth of 40 miles.

Depths which exceed 18,000 ft. are called Deeps and have names given to them. About 60 such ocean pits have so far been charted, of which the Pacific claims more than a half. The largest is the Voldiva, which extends around South Africa and lies partly in the South Atlantic and partly in the Indian Ocean. It covers an area of 1,136,000 sq. m., while the Murray in the North Pacific, and the Aldrich in the South Pacific, are nearly as extensive.

(44) Deepest Sounding made in the oceans without striking bottom } 32,644 ft.= 6 m. 1 f. 101 yds.

Note.—Several soundings have been made by a Japanese survey ship in the Tuscarora Deep in the Pacific off the east coast of Japan and about 1,200 miles west of San Francisco. Some accident to the sounding wire prevented a continuance of the operations. This region of the ocean has not yet been thoroughly mapped. Oceanographers believe that this Deep is at least 60 miles long, with an indeterminate width and depth.

(45) Greatest Depth in the ocean yet sounded } 35,401 ft.= 6 m. 5 f. 140 yds. (*Encycl. Br.*, 1929)

Note.—New soundings are constantly taken in the oceans. The deepest part of the ocean yet sounded is the Mindanao Deep in the Pacific. It

extends north to south about 45 miles off the coast of Mindanao, the second largest and southernmost island of the Philippine group.

This record depth in the ocean exceeds the elevation of the highest mountain peak on land, Mt. Everest, by 6,256 ft., and its discovery makes the known variation in the level of the earth's crust a little over 12 miles.

The pressure at the bottom of this great 'hole' would be 7 tons to the square inch or about 1,065 atmospheres.

(46) Extent of Elevation of the entire Sea-bed if all the oceans on the globe dried up . . . 170 ft.

Note.—The text of this item may look somewhat cryptic, but the meaning will be clear when we explain that, if all our oceans were to evaporate, the salts which would remain behind would form a crust 170 ft. thick over the whole sea-bed.—(*Negretti & Zambra*)

Concluding Remarks

The interior of the ocean has many geographical features in common with the land surface of the earth. The seas thus have their mountains, plateaux, precipices, shelves or ledges of rock with abrupt brinks; gorges known as gulches; caverns or trenches; valleys; plant life ranging from isolated plants and bushes to vast forests growing in the valleys; animal life of great diversity and in abundance, and last but not least, archaeological ruins, the remains of lost cities and islands.

The bed of the ocean, like the land surface, is subject to earthquakes or 'seaquakes' as they are sometimes called. A severe earthquake, believed to have originated in the Pacific Ocean off Central America, was recorded on 18th June 1932 at the observatory at West Bromwich in England, about 6,000 miles away. The oscillations in the seismograph produced by the shock were so violent that one of the levers of the instrument became dislodged. Seaquakes are often accompanied by volcanic outbreaks, and these two agencies have the effect of altering the sea-bed and causing displacement of the waters. Eruptions of submarine volcanoes have often been observed. They are accompanied by many of the phenomena noticed in land volcanoes—columns of smoke and ashes, and incandescent stones catapulted from the submarine craters with enormous force. On 16th January 1931 huge columns of smoke were seen

rising from the sea at some distance off the Mexican seaport of Mazatlan, the shore being strewn with dead fish. Evidently an undersea volcano was in action. In India too evidences are now and again afforded of submarine disturbances. At Porbandar in Kathiawar quantities of dead fish have been washed up from time to time which could have been due to no other cause.

The extreme depths of the ocean are cold, absolutely and perpetually dark, and the pressures there, as has been noticed, are enormous. The temperature at the bottom of the deepest seas, except in the frigid zones, is 2° to 3° C. (35·6° to 37·4° F.) above freezing-point. The ocean-bed where the depth is not great is for the most part composed of sand, but the deeper floors are covered with soft, sticky ooze, mainly of organic origin, being formed by the decay of sea plants and the disintegration of the shells or skeletons of microscopic animals, mixed with the volcanic dust borne away by the winds from time to time from land volcanoes in action. The sea-bed is also the receptacle of most of the meteorites that fall from the sky, as the major number of those which fall on the earth must be falling into the ocean, considering that over 7/10ths of the surface of the globe is occupied by water.

Marine zoology is a vast subject. In the domain of biology it is an empire by itself. There must be more varieties of animal life in the ocean than on land. The largest animal is the Whale, which in the great northern rorqual or blue whale, the largest creature on the earth, is known to grow to a length of over 100 feet. A full-grown member of this species weighs 120 tons or more and its circumference is between 30 and 40 feet. Taking the weight of a full-grown man as 135 lbs., that of a full-grown blue whale will thus be equal to the weight of a crowd of 2,000 men! Other members of the mammoth class are the high sea Whale Shark which grows to 70 feet; the man-eating Shark which reaches a length of 40 feet; the Saw Fish 20 to 30 feet long; the Devil-fish measuring up to 18 feet across and weighing 1 to 5 tons; the Sea Elephant, the largest species of seal, which measures 20 feet in length and 15 feet in circumference; the Sea Horse or Walrus which attains a length of 20 feet; the Sea Unicorn or Narwal, 12 to 20 feet long, with an enormous projecting tusk, 6 to 10 feet in length, spiral in form and, like a screw, shooting straight and tapering to a point; the Sword Fish which reaches a

weight of over 600 lbs. and a length of 16 feet and is armed with a 3-foot bony sword; the 10-foot Dolphin and so on. Among dangerous reptiles is the Sea-snake, which frequents the tropical seas and is abundant in the East Indian Archipelago. It has large platelike shields on its snout and a flattened rudder-like tail. It grows to 10 feet, and its venom is said to be six times more virulent than that of the cobra or Russell's viper and eight times as powerful as the krait's. As many as 29 species of this reptile have been found. It appears that sea-snakes are occasionally carried to the lower reaches of rivers by the currents. In June 1932 six persons at Māyāvaram in Southern India, while bathing in the Coleroon, a branch of the Cauvery river, were bitten by sea-snakes with fatal results. Similarly the giant estuarine crocodile, the largest and most ferocious of saurian reptiles, which inhabits salt waters in the rivers, is often found at sea. A full-grown animal attains a length of 30 to 33 feet! From the fact that a crocodile 16 feet long recently caught in a pond in the Philippines weighed 19,800 lbs. or nearly 9 tons, the largest salt-water crocodile probably weighs more than 16 tons or over four times as much as the largest hippopotamus. Among other reptiles is the giant Green Turtle found in the tropical parts of the Atlantic and Pacific Oceans. It is 6 to 7 feet long and attains a weight of 1,000 lbs.

Among other strange creatures, which are found only in the warmer seas, are the Diodon and the Tetrodon, so named on account of their having only two and four teeth respectively, and the Globe Fish. These are all called by the general name of Balloon Fish. The Diodon and the Tetrodon are armed with spines and have the power of inflating their bodies by swallowing air and making it pass into cavities beneath the skin, which enables them to float on water like a hollow rubber ball and gives them an almost spherical shape. As their bodies distend, the spines erect themselves. In the case of the Globe Fish the air swallowed by it passes into a ventral sac and inflates the whole animal like a balloon, thereby enabling it to float.

Another curious inhabitant of the tropical waters is the Flying Fish, which has large and long pectoral fins and a caudal fin whose lower lobe is very long. With powerful strokes of the tail it rushes through the water and, with the initial velocity acquired, leaps into

the air where it can sustain itself for a time. With its pectoral fins outspread it flies a considerable distance, sometimes as much as 200 yards. The Catalina Flying Fish of the South Californian waters is one of the largest known species, sometimes 18 inches in length. Its flight power is strengthened by long ventral as well as dorsal fins. It is believed that these fishes fly to escape from the attacks of larger fishes, especially the dolphin. They are marine examples of those strange land creatures, the flying lizard, the genus Draco, of the Malay Peninsula and Borneo, the flying lemur of Java, the flying frog of Java and Borneo, the flying snake of Borneo, the flying mouse of Australia and the flying squirrel of North America, which (except in the case of the flying snake) are provided with membranes which serve as parachutes.

The whale is not a fish in the technical sense, but a warm-blooded mammal. In spite of its enormous size it has a mortal enemy in the sword-fish—the 'gladiator of the sea'—though the latter is considerably smaller. Owing to its formidable weapon this fish is dreaded not only by other monsters of the deep but also by mariners. It has attacked stout wooden ships with disastrous effect. Its sword has penetrated 11-inch oak timbers and even copper-sheathed hulls. A thrilling account is given by some whale-fishers of a long, fierce but drawn battle which they witnessed between a huge sword-fish and a whale, in which the former as usual was the aggressor. Throughout the fight the sword-fish adroitly kept clear of the whale's powerful weapon, the tail. Again and again it took a leap of 8 to 10 feet out of the water and viciously struck at the head of its foe with its sharp blade. At last with a supreme effort the whale leaped 6 to 7 feet into the air and came down with a mighty splash, when both the combatants disappeared.

The terrible strength possessed by many of these sea-giants is often displayed in their chance encounter with man. A huge octopus, a fish which can be ferocious at times, once became entangled in the anchor of a small fishing boat at an Australian port and gave its occupants the thrill of a lifetime. It was as much as they could do to shake off the monster and save their lives. Another deadly enemy of fishermen, which is found in the tropical seas, is the saw-fish. It possesses tremendous strength as well as savagery. It is armed with a bony lance with a serrated blade. One such giant

recently got under a 20-ton yacht off the Panama coast and towed it for five hours until at last it was captured. It was 31 feet long and weighed 5,700 lbs., more than 2½ tons. The barracuda, otherwise known as the sea-wolf, a fish which averages 10 feet in length, is notorious for its ferocity and the deadliness of its bite. On several occasions it has attacked swimmers and mangled them. The sting ray is another dangerous fish. It can inflict a poisonous wound with its long, flexible, whip-like tail which is armed with a barbed bony lance near the root. But the villain of the seas most dreaded by swimmers and by fishermen venturing out in small craft is the man-eating shark. We often hear of dramatic battles between this fish and man. Sometimes fishermen lure these monsters to their doom by throwing quantities of animal blood into the sea and spearing them as they rush to the surface attracted by the smell of the bait, for the shark has an acute sense of smell. A shark's stomach is sometimes a veritable conjuror's box. The stomach of a large shark caught at Honolulu contained among other articles a horse's leg with hoof and shoe, a piece of turtle-shell, a tin can six inches square and a gunny bag! In the southern seas there is a species of seal called the sea-leopard on account of the whitish spots on the upper part of its body. It is a powerful brute, sometimes 6 feet long, and when fully grown it can bite off a man's hand or foot.

The gymnotus or electric eel found in the marshes of Brazil and Guiana has a marine example in the Torpedo or Electric Ray, a fish which has its habitat in the warmer seas. It weighs from 60 to 200 lbs. Nearly 20 species have been discovered. It owes its electric power to special paired organs between the head and the pectoral fins, consisting of a large number of vertical gelatinous columns with membranous partitions between and provided with numerous filaments branching from the vagus nerves, the whole apparatus functioning like a voltaic battery. Under excitement the animal's nerve force is transformed into electric force through the medium of the electric organs, and the animal subjected to the shocks becomes numb. This singular power of the fish was known to the ancient Greeks and Romans, as a powerful species of it occurs in the Mediterranean.

It is quite common for a larger fish to prey on a smaller one. The shark eats the comparatively small flounder, which in turn

feeds on the tiny minnow. But it is extremely rare to come across a fish which will attack fishes larger than itself for food. A dog-fish, a small but rapacious species of shark commonly found off Southern California, has been seen to give battle to a cod bigger than itself, which soon fell a victim to the fierce attack.

One remarkable variety of fish life in the ocean is the Coloured Fish. The 'butterfly' cod is a curious fish with alternating bands of black and white around its body. It consequently looks like a monster butterfly. There is one type of fish, vioiet and gold-green in colour, called the Isabelle, and another kind known as the Coquette, with flaming yellow, black and vermilion stripes. The 'chambered nautilus', a denizen of the southern seas, is a jelly-fish of a beautiful purple and cobalt-blue colour. Contact with it produces an effect similar to scalding. The Opah, a beautiful fish about 4½ feet long found in the eastern seas, the Atlantic and Arctic Oceans, is remarkable for its extraordinarily rich colours. The upper part of its back and sides is green with tints of purple and gold, passing into yellowish-green below, the fins being bright crimson. In the eastern waters of America is found the sculpin, another remarkable fish. It has a long horn and a large head furnished with sharp spines, with which it often wounds unwary fishermen. Its mouth is big enough to enable it to swallow fishes much larger in size than its own comparatively small body! It changes colour with the same ease as a chameleon. In spite of its terrible weapons the sculpin generally prefers to be left alone, and trusts to its ability to change colour, to hide its presence. When lying in the shelter of a dark rock covered with crustaceans and pink, brown or green plants, the sculpin will be seen to have a dark colour mottled with pink, brown or green. On a patch of brown vegetation it will be all brown, and on a bed of white sand it will be as pale as the sand.

But by far the most interesting fishes to be found in the ocean are the 'luminous fishes', which may be aptly termed the 'stellar system of the ocean'. They are provided with luminiferous organs which enable them to pursue and capture prey in the dark depths. Besides those mentioned already, there is a deep-sea fish of the angler family called the *Linophrynida*. It has a luminous tentacle shooting up from its nose, and is the proud possessor of what is an

extreme rarity in the finny race—a beard, which trails under its lower jaw, and this beard is luminous! It is armed with formidable spines on the head and back, and long sabre-like teeth. There is another species of the same family, the *Photocorynus Spiniceps*, an inhabitant of the Gulf of Panama, with similar spines and teeth. Its female carries her mate, an animal much smaller than herself, as a permanent fixture on her forehead! A finished example of wifely devotion, or—as some may look upon it—of a submissive wife and a hen-peck*ing* husband, for the male is a crown of thorns!

The Sun Fish, an animal which looks like the head of a large fish severed from the body and often attains a diameter of 12 feet, and in rare cases a weight of 17 cwts. or more, has been seen to glow in the dark like a white-hot cannon-ball. In one species of shark, the *Squalus Fulgens*, the entire surface of the body gives out a greenish lurid light, which makes it appear a ghastly object like some monster spectre.

The ocean waters, especially in tropical latitudes, are very rich in noctilucent polyps and pyrosomes. The tentacled sea-pen, a feather-shaped polyp, dances in the waters in a greenish light. The pyrosomes or 'fire-bodies' which, along with other luminiferous animalcules are known as *Noctilucae* or *Radioflagellata*, are minute molluscous animals which unite in vast numbers and form a hollow transparent cylinder no larger than a finger. Myriads of noctilucae dance through the obscurity of night like tiny glow-worms. A traveller relates an amusing incident about the effect of this phenomenon on land animals.* As he landed one evening on the shore of a tropical sea, a dog close by began to bark at him furiously. He filled a glass with the noctilucous sea-water and threw the contents full at its face. Terrified no doubt at the sight of what looked in the dusk like a quantity of liquid fire, the dog sharply took to its heels, though it kept barking from a respectful distance!

The production of light by the larger luminous fishes and the marine animalcules, as also by certain land organisms, was for a long time described as 'phosphorescence'. Though in its real sense this term means no more than the property possessed by certain bodies of emitting light in the dark in the manner of phosphorus, many zoologists nowadays discard its use lest it should be taken to imply

that the phenomenon is due to the presence of that inflammable substance in the bodies of these creatures, and call it *bioluminescence* instead. But this light-producing device is almost absolutely cold; in other words, almost the entire chemical energy of the process is converted into light without any generation of heat. The emission of light is attributed to the oxidation of a compound known as *luciferin*, in the presence of a ferment called *luciferase*. Professor Newton Harvey, a zoologist of Princeton University, U. S. A., has recently announced the results of some careful observations he carried out on a few luminous deep-sea fishes. He obtained two examples of a fish dredged near the Bermudas from a depth of about 4,800 ft. and succeeded in keeping them alive by putting them in icy sea-water of a temperature equal to that occurring in their habitat. They were over 12 inches long, and had luminous organs on each cheek, which gave out a bluish light when the fishes were handled, and two lateral rows of large luminiferous devices, besides smaller ones distributed all over the surface. Another kind of luminous fish examined by Harvey was a small shrimp, barely an inch and a half long, dredged off the Bermuda coast from a depth of between 3,600 and 4,800 ft. He studied it also in a living state in icy sea-water. He found that, under the stimulation of a touch, the shrimp ejected a cloud of bluish light from glands near the mouth, and this secretion, diffusing through the sea-water, enveloped the whole body in a flood of light.

On land there are certain animal as well as vegetable organisms which are luminescent. The most important of the former are a genus of beetles familiarly known as the fire-fly. Some species of this insect give out a steady light, while others like the glow-worm flash light intermittently. Different sub-species, again, emit light of different colours—bluish, green, greenish-white, yellow or reddish. The light is produced inside cells and emanates from two or three eye-like tubercles beneath the abdomen. In some species the eggs and pupae also are luminescent. The *Elater* or *Pyrophorus noctilucus*, of which there are about 90 sub-species, is one of the brightest of fire-flies. It is found only in America in the vast area extending from southern United States to the southernmost countries of South America. Its light is so brilliant that in Hayti (San Domingo) in the West Indies and some other tropical parts of

America these insects are used for purposes of illumination, and 8 or 10 confined in a phial send forth sufficient light to enable a person to read or write! In the Amazonian forests fire-flies emitting green, yellow and red light assemble in multitudes on the plants and trees overhanging the banks of small streams, and their beautiful lights mirrored in the water turn these areas into little fairylands. Besides fire-flies there are several other orders of animal organisms, for instance the centipede family, some of whose species are luminescent. But even more interesting than the fire-flies are the luminous plants, which consist of two groups. There are certain species of fungi growing in decayed wood, whose mycelium or fine thread-like fibres are luminous. Sometimes both the mycelium and the pileus or cap emit light. Some remarkable species of mushrooms are found in the forests of Borneo, Brazil and other tropical countries. Travellers say that they glow with a steady, continuous light so powerful as to illuminate a whole jungle! Some of the plants are a foot high, upwards of a foot in diameter and weigh several pounds. In one case, an explorer plucked one such mushroom and on placing it on a newspaper found that he could easily read the print! A noteworthy feature of these luminous plants is that they shine both night and day. In all these cases the light is produced by the same chemical agencies as in the luminous fishes.

It is exceedingly rare to come across aquatic animals that utter cries or emit other sounds. The hippopotamus, the 'dreadnaught' of the African rivers, grunts, snorts and bellows at times, and when it is infuriated its grunt is powerful enough to be heard a mile away. The alligator bellows loudly at night. Among marine creatures, the giant turtle of the Galapagos Islands in the Pacific off Ecuador, South America, bellows at a certain time of the day; the sea-lion, a large member of the seal family found in the southern hemisphere and in certain parts of the North Pacific, barks or roars when hungry; the gurnard, a fish inhabiting parts of both the Atlantic and the Pacific, produces a curious sound resembling grunting or grumbling when taken out of the water and is therefore also called the 'grunter'; the 'croaker', a small fish of the Atlantic but also found near the coast of California as well as in fresh water, makes a croaking noise when caught, and the maigre or shade-fish, common in the Mediterranean, sends forth a sort of whirring noise as it moves

through the water. In the salt lagoons of Batticaloa, an eastern port of Ceylon, are found 'singing fish', believed to be shell-fish, which emit musical notes.

It is a wonder how deep-sea fishes manage to live at such enormous depths. The pressure on every square inch of the body of every animal that lives below 15,000 ft., a level at which the pressure approaches 3 tons per square inch or 450 atmospheres, will be over 22 times the pressure that will drive an express railway train! Deep-sea fishes cannot live in shallower waters, and have a well-defined 'ceiling' in mid-water. Those which climb far up in pursuit of prey are unable to return to their haunts and die through distension of their organs caused by the considerable diminution in the pressure on their bodies. The Viper Fish, a denizen of the icy regions of the seas, lives at a depth of 3,000 ft. When forced up into the warmer waters above, it gives out a sort of hissing or fizzing sound like that produced when the contents of a soda-water bottle are poured into a glass, as a result of the greatly reduced pressure on its body.

A perhaps unique instance of sea-fishes adapting themselves in the long course of time to the changed conditions of life in fresh water has come to our notice. The great fresh-water lake of Nicaragua in Central America is inhabited by several kinds of sea-fish including the shark. It is generally believed that this lake was in comparatively recent geologic times an inlet of the Caribbean Sea and that as the result of a volcanic upheaval the sea life of this inlet became isolated and was imprisoned in the inland lake thus formed. Owing to fresh water continuing to flow into it, the lake gradually lost its salinity and in the course of centuries became a fresh-water lake, but its marine life has in the meantime adapted itself to the altered conditions. The same types of life as occur in it are found to-day inhabiting the salt waters of the Caribbean Sea. Lake Nicaragua, however, still maintains an indirect connection with the Caribbean by precipitous falls leading to a river which empties its waters into that sea at the port of Greytown.

Marine fauna and flora are more abundant in temperate and polar seas than in tropical waters, but there is greater variety of life in the warmer seas.

The water of the ocean, like any other liquid, absorbs a certain amount of the gases with which it comes into contact. The peculiar breathing apparatus or gills of the fish only function if the air absorbed by them contains a greater percentage of oxygen than does the atmosphere. At the surface of the sea the oxygen content is about 34 per cent of the whole absorbed air, while it is present to the maximum extent of only 21 per cent in the atmosphere. Important discoveries have been made by Dr. Erik G. Moberg, oceanographer, on the subject. By a chemical study of thousands of samples of water taken from various depths in the oceans, he finds that there is less free oxygen in the waters of the Pacific than in those of the Atlantic, and there is more in the water of great deeps of both oceans than in that at moderate depths. The highest oxygen content in the Pacific water was found at the surface, where it was nearly saturated. The content diminished with depth up to a certain point, until at 2,000 ft. it was less than one part in a thousand of water, but from this depth downward, the oxygen content increased again until it attained its maximum at the floor of the ocean. The highest oxygen ratio in the deepest waters was found to be 3·45 parts per thousand of water. A lower percentage of oxygen in the depths than at the surface is explained by the fact that a large quantity of it is consumed by the marine organisms and cannot be directly replaced.

The popular impression is that the sea is always salty, but explorers have recently found a 30-ft. surface layer of fresh water at some places in the Arctic Ocean. The explanation of this apparent paradox is that the melting snow and ice from glaciers and icebergs supply the fresh water. There may be similar layers of fresh water in the Antarctic due to the same causes. At the entrance to the Baltic Sea, in the Skagerrak and Kattegat, patches of fresh water are also encountered that have flowed down from the surrounding hills.

The officers of the British steamer 'Asphalion' in 1931 came across a magnificent phenomenon in the Atlantic a few hundred miles north of the South American Guianas. As the vessel was steaming into a heavy south-west swell she met with rough broken seas, but the waters appeared smooth, for 'each combing breaker left a shadowless wake of white, boiling water'. The expanse of water

looked like a 'sea of milk' and continued to do so for fully five hours, 'throwing the horizon of ink-black sky and milky sea into bold contrast'.

This temporary milky appearance of a portion of the sea and the discovery of fresh water layers in the Arctic and elsewhere may remind our Hindu readers of the fifth and the seventh of the seven oceans with which Hindu mythology surrounds the earth—Kshira-sāgara (ocean of milk) and Jalārṇava (ocean of sweet or fresh water).

Sailors often report having seen the waters of the ocean boil and bubble away. The action, they say, is so vigorous that the surface at times becomes invisible owing to the rising vapour. An explanation of this phenomenon is advanced by Mr. Albert Noden, oceanographer, who observed an occurrence of this kind at Biarritz, a French port in the Bay of Biscay. He attributes it to sudden changes in the weather. The previous night there had been a sudden fall in the air temperature to a degree or two below freezing-point. The change was too rapid for the sea-water to respond to. In the morning when the ocean appeared to be boiling, the temperature of its water was found to be 15° to 20° higher than that of the air immediately above. The relatively warm water was giving off vapour which condensed the moment it rose into the colder air and formed a layer of cloud on the sea surface.

There is, however, one small corner of the ocean where the water is actually warm and remains so throughout the year. Strange to say it is in Iceland, which at its northern limits is touched by the Arctic Circle. There is a spot in this island where the Atlantic washes through a lava ridge filter so hot that a lagoon of warm water forms behind it. To the inhabitants near by and to visitors this lagoon affords a delightful place for sea-bathing.*

The age of the ocean according to Jeffreys' calculations is more than 1,300 million years.

We shall close this brief survey with an attempt to arrive at an estimate, though a rough one, of the weight of the Ocean. We know its superficial area (141,038,687 sq. miles) and mean depth (12,450 ft.), and can find out the pressure at this depth. We are adopting the average depth in our calculations, and in doing so assume a level bed for the ocean. The area of such a bed will no doubt be a little

less than the above mentioned superficial area of the water, but if we take the two areas as equal, the difference will not materially affect the result of our calculations. Now the pressure on any area of the sea-bed is the weight of the column of salt water over it, and at a depth of 12,450 ft. the pressure will be 2·44 tons to the *square inch*. We have thus only to calculate what the pressure will be at the bottom over the whole area of 141,038,687 $\times$ 5280^2 $\times$ 12^2 *sq. inches*. We thus find the weight of the Ocean to be 1·38 quintillion tons, about ·0002 that of the whole earth. Abbot, it may be noted, says that the world's water weighs *not less than* 1·25 quintillion tons.

Throughout the whole ocean there are about 35 lbs. of salts to every 1,000 lbs. of sea-water, so that the total quantity of saline matter in all the oceans amounts to roughly 48·3 quadrillion tons. It is estimated that every year half a billion tons of salts are carried to the sea by the American rivers alone.

CHAPTER III

1) The Earth's Land Surface

2) The Earth's Atmosphere: The Lower Troposphere

Come forth into the light of things,
Let Nature be your teacher.
—*Wordsworth*

There is nothing beyond the pleasure which the study of Nature produces. Her secrets are of unfathomable depth, but it is granted to us men to look into them more and more. —*Goethe*

We now start on our exploration of the land surface of the globe and its gaseous envelope. Our first idea was to begin at sea level, but curiosity led us to investigate whether there was any tract of land below that level comparable to a respectable ocean-bottom. As a result we commence our pilgrimage from a place which, so far as its extent of depression is concerned, may be described as a miniature Hell on Earth! But we may digress a little before starting.

The Earth's Atmosphere or Gaseous Envelope consists of two layers. Its 'ground floor' or lower layer is called the Troposphere which is the storm-bearing area, and the second or upper layer, the Stratosphere. The two layers are separated by a boundary region known as the Tropopause. The Troposphere is a curved layer running parallel to the earth's curved surface with an upthrust in the central part.

(1)	World's Lowest Tract of Land—an extensive plain at the base of Mt. Mauna Kea, Hawaii or Sandwich Islands, North Pacific	18,000 ft. or 3 miles 3 f. 60 yds. below sea level (*Encycl. Br.*, *1929*)

Note.—For further particulars *vide* Item 82.

(2)	World's Lowest Lake—the Dead Sea	1,292 ft. below sea level

Note.—It is a deep-blue lake about 53 miles long with an average width of 10 miles and a maximum depth of 1,309 ft. It lies in a vast depression, and

its shores form the second lowest land in the world. It is enclosed on the east and west by bare, steep mountains composed of either limestone or sandstone or strata of both. In places along the shore tower up precipitous cliffs to a height of about 2,000 ft. The ground around the lake consists of salt-marshes, desert plains covered with salt incrustations, hillocks of rock-salt and a marshy plain covered with reeds and desert vegetation. For the most part, therefore, the Dead Sea is surrounded by a vast, sterile, desolate wilderness. The sun's rays are scorching, and the air is salty.

While the proportion of saline matter in the ocean is 4 to 6 per cent, the Dead Sea has a salinity of 23 to 25 per cent. Its water is so salty and bitter that no animal life can exist or survive in it, and fish carried down by the currents of the Jordan river die in a short time. The abnormal salinity of the lake is due to the washings of the salt-marshes and rock-salt hills and to the very rapid evaporation caused by the fierce rays of an unclouded sun, and to a lesser extent to the brackish springs in the region. The density of the Dead Sea water is roughly 1·16 and it increases from north to south, so that at the southern end it goes up to 1·25. A person who wades in the lake finds when he is about neck-deep that he is swept off his feet and that, while swimming, the shoulders remain the whole time above water.

The mineral resources of the lake are now being exploited by a British Company called the Palestine Potash, Ltd. As it was found that the water at a certain depth contained more salts than the surface water, iron pipes have been laid at a depth of 175 ft., and the water is carried by means of wooden pipes to the evaporating pans. Owing to the intense buoyancy of the water, the divers employed to help in laying the pipe-line under water met with considerable difficulty in their operations, and extra weights had to be attached to their suits to enable them to dive to and stay at the required depth. The salts present other than sodium chloride (common salt) are potassium chloride and bromide, calcium sulphate and chlorides of calcium and magnesium, the most plentiful being magnesium chloride, the percentage of which to common salt is nearly 2 to 1. The quantity of potassium salts in the lake is estimated at something like 2 billion tons, while that of magnesium chloride may amount to 30 billion tons or more. Fresh water for the needs of the Potash Works and the working community is obtained from the Jordan. In 1931 over 13,000 tons of carnallite (crude potash salts) were harvested by mechanical methods, and a small plant installed in February of that year was able to produce over a ton of refined bromine daily. Besides this product, the Dead Sea waters are now made to yield large quantities of mineral salts useful for the preparation of fertilizers, chemicals and medicinal drugs. The term 'Dead-Sea fruit' may therefore shed its sinister import and acquire a new meaning hereafter!

(3) World's Lowest Group of Thermal or Hot Springs—those in the Jordan Valley, Palestine } 1,200 to about 684 ft. below sea level

Note.—Near the shores of the Dead Sea and in its basin lie numerous warm sulphur springs. Copious streams of this spring water flow into this lake along the mountain gorges. The waters of the Dead Sea possess valuable curative properties and are particularly beneficial in rheumatism and skin diseases. There are hot springs also around the Sea of Tiberias, a smaller lake situated due north of the Dead Sea and connected with it by the Jordan river. It has several biblical names and is mentioned in the Gospels as the Sea of Galilee. It lies 684 ft. below sea level, and at least one spring lies below the level of the lake.

These springs have been famous since the time of Joshua (1426 B. C.) The temperature in the largest is 57·8° C. (136° F.).

(4) Situation of the World's Largest Lake—the Caspian Sea } 84 ft. below sea level

Note.—It is a salt-water lake about 800 miles long and 100 to 275 miles broad. Its maximum depth is 3,104 ft., and it is the second deepest lake in the world.

(5) Highest Mound built by a Bird ... ... 14 ft.

Note.—In Northern Territory and Queensland in Australia is found a large species of jungle-fowl, or scrub-fowl as it is also called. Its scientific name is *Megapodius Tumulus* or *Megapodius Duperryi*. By scraping together earth, sand, stones and decaying vegetable matter, it builds its nest, an immense mound rising like a crater. In the centre at the top, at a depth of 2 to 3 ft., it deposits its eggs which are hatched, not by incubation but by the heat generated by the decomposing vegetable mass. Plenty of these mounds are met with also in the islands about Endeavour Strait and round Cape York. One mound measured by the ornithologist Gould was 14 ft. high and 150 ft. in circumference.

(6) World's Highest Termitaria or White Ant Nests—those in Northern Australia (Northern Territory) } 20 ft. (*Encycl. Br., 1929*)

Note.—Termites, or white ants as they are popularly called, are among the most highly organized in the insect kingdom. They are principally confined to tropical countries and are found in great abundance in Northern Australia, South America, East and West Africa. Their nests are pyramids or cones built up of particles of earth cemented so firmly that they are said to be capable of bearing the weight of three or four men. The termitaria of Northern Australia, reach a maximum height of 20 ft. and are 12 ft. in diameter at the base. Hundreds of termite nests, 15 ft. high or more, are found in parts of Uganda in East Africa, shooting up at regular intervals, the flanks of the bigger ones being broken by little accessory cones. The interior of the nest is a veritable labyrinth divided off into numerous irregular cells communicating with each other by galleries. Every termite colony has its little

its workers. Entrance to the interior is afforded by hidden pathways and underground passages. The deeper recesses are the rearing places of the brood. In a large chamber in the heart of the nest reside the king and the queen which are much larger than the other members of the colony, and the royal apartments are guarded by a regiment of soldiers. The queen is a repulsive creature with an abdomen enormously distended with eggs, and has a skin so transparent as to render visible the tubes and strings floating about in the liquid interior. A termite-queen has been found to lay 1,000 eggs in one night. The eggs, as they are dropped, are received and carried in their mouths by relays of workers to minor chambers throughout the nest. The chief enemies of the termite race are spiders, toads, lizards and bats.

The French naturalist, Dr. F. A. Pouchet, refers in his book *The Universe* to termitaria which contain chambers so large that a dozen men can find shelter in some of them, and says that hunters place themselves in them to lie in wait for wild animals !

(7) Height reached by the world's first experimental, manned, Rocket-driven Aeroplane—Germany's 'Man-carrying Fireworks'	About 75 ft.

Note.—The hero of this daring experiment was Fritz von Opel, a famous German sportsman, who helped in the development of the spectacular rocket-propelled motor car. The rocket-plane in which he made his experimental flight was a bullet-shaped monoplane, a 'winged sky-rocket'. 16 powder rockets, each 18 inches long and 3 inches in diameter, were placed in the metal compartments at its rear, their recoils being counted upon to propel the machine. Three 10-lb. rockets were exploded to launch it and the others exploded during the flight. The rockets, as they burst, ejected balls of flame and clouds of smoke. The following graphic description of the flight appeared in the Press in October 1929 as a special cable from Frankfurt :—

'A dense cloud of smoke with a ball of fire in the centre, moving with lightning speed through the air with a deafening din and suddenly falling to the earth, caused consternation in the countryside. The phenomenon was Fritz von Opel who, strapped into the asbestos-lined cockpit of a rocket-driven aeroplane (without engine and propeller) of which he is the designer, was hurtled into the air by means of a rocket-driven truck, which ran along the rails till it struck a buffer, the aeroplane being thence catapulted into the air, a battery of rockets behind the wings continuing the propulsion. The machine travelled over a mile. The pilot was exhausted. This is the first time that a rocket machine has had a passenger.'

(8) Elevation of the World's Coldest Town—Verkhoyansk, north-eastern Siberia, 67° 30′ N., 134° E.	160 ft.

Note.—In winter the piercing Arctic winds sweep over the vast, inhospitable, treeless plains known as tundras which lie in the parts

of both Asiatic and European Russia lying within the frigid zone. These winds traverse also sparsely wooded regions such as those north of the Verkhoyansk Mountains in north-eastern Siberia. There is a small area here lying on both sides of the Arctic Circle and separated from the sea by nearly 1,000 miles. Its annual rainfall is below 10 inches, and while exposed to the chilling blasts of the north, it is absolutely cut off from the warmer south-west winds by the great Central Asian plateaux. In the winter, which is extremely severe, the ground lies buried in snow, and the atmosphere becomes laden with frozen vapours. Rivers freeze right to the bottom. Trees become frozen to their core, and the axe, in spite of the hardest strokes, fails to make an impression upon them. The average winter temperature at Verkhoyansk, a town in this region, is –49°C. (–56°F.). Sometimes the thermometer drops to –65°C. (–85°F.), the lowest temperature recorded being –69°C. (–92°F.). The mean summer temperature in this area 60°F., and with its average winter temperature of –56°F. it has the enormous range of 116°F. In fact there is a greater variation in the temperature in this region than is found anywhere else on the globe. A geologist of the Russian Academy of Sciences has discovered a still colder spot in this area in a valley of the upper reaches of the Indigirka river which are surrounded by mountains 7,000 to 10,000 ft. high. The mean temperature here from December to February is from 3° to 5° lower than that at Verkhoyansk. The last Meteorological Glossary mentions the lowest temperature registered on the surface of the earth to be –93·6°F. (–69°·8 C.). Even in Antarctica the average temperature has been found to be –51° C. (–60° F.) in winter, and near the ice-cap of Greenland –50·5° C. (–59°F.) in January and February.

A member of a mountaineering party to Mt. McKinley (20,300 ft.) in Alaska reports having found at 15,000 ft. thermometers which had been left by a previous expedition and the arrow-markers of which pointed to temperatures lower than –95° F. He adds that there are also indications that a temperature of –100° F. (–73·3° C.) had been reached.

If such are the records of extreme cold the earth has to show, what are the records of extreme heat on it? It is well known that of all regions the tropics are the hottest, but even here it is the desert

areas where the intensity of summer heat is most marked. So far as India is concerned, the Pat Desert in Upper Sindh tops the list. Jacobabad, the chief station in Upper Sindh Frontier District, is the hottest town in India. One June day in 1919 the thermometer here rose to 127° F. The highest temperature recorded at this station during the summer of 1932 was 123° on 23rd May. Maximum temperatures a degree or so higher than 120° have also been recorded occasionally at other places both in and outside Sindh, chief among these being Hyderabad (Sindh), Deesa, Jodhpur, Multan, Montgomery, Lahore and Dera Ismail Khan. As the land in and near Jacobabad is well irrigated and the town is more or less sheltered by trees, the summer temperatures at the villages in the most arid parts of Pat Desert are probably some degrees still higher than at Jacobabad. Owing to its most scanty rainfall, Upper Sindh has a longer summer than any other part of India. Its Frontier District is hotter than even Iraq or Arabia. At Baghdad the highest temperature recorded is 123°. The hottest area in Asia is the Jordan Valley in Palestine, where the thermometer in summer sometimes rises to 130°. The only other region on the earth where a still higher temperature has been registered is western Sahara, where the highest day temperature recorded is 132·8°. The highest night temperature recorded in the whole of Sahara Desert is 104°. In summer, at Shikarpur and other places in Upper Sindh the readings sometimes do not fall below 100° even at midnight for weeks together. Yet the extremes of temperatures here are remarkable. In winter the temperature at night often falls below freezing-point, and ice forms even as late as February.

(9) Vertical Height or Height above the pool of the World's Broadest Waterfall—Niagara ('Thunder of Waters')	150 ft. on Canadian side and 164 ft. on U. S. side

Note.—Niagara's total breadth at the brink is 4,750 ft., but an island in the middle named Goat Island, about 1,000 ft. wide, divides the Fall into two parts. The width on the Canadian side is over 1,760 ft. and on the U. S. side roughly 2,000 ft. The waters plunge into a chasm about 1,000 ft. wide, and it is estimated that about 11,170 tons of water precipitate themselves into the chasm every second! The Falls have been harnessed for the generation of electrical energy, and part of this terrific force is used for the lights which are turned upon Niagara at night. Attempts are being made to broadcast the roar of Niagara across the Atlantic.

(10) Height to which a Geyser has been found to throw up jets of hot water at an eruption } 250 ft.

Note.—Geysers are boiling springs which, like volcanoes, are subject to intermittent eruptions. At such times they eject columns of boiling water, steam, mud etc., sometimes with loud explosions. Their high temperature is largely due to the heating of the walls of fissures in rocks which are subjected to volcanic influences, whereby the water is gradually raised to the boiling point under pressure and explodes into steam when the pressure is relieved. An interval of time must elapse before there can be a repetition of the process. Geysers result generally after powerful volcanic eruptions in their vicinity have ceased. They are most numerous in the Yellowstone National Park Area, Wyoming, U. S. A., and in Iceland, one of the most volcanic regions on the earth. There are nearly 100 geysers in each of these two countries. The Yellowstone region contains, besides the geysers, upwards of 3,000 non-eruptive thermal springs. The largest geyser in this area is the 'Giant Geyser', which begins an eruption by filling its basin with boiling water, forming a well about 22 ft. across, with a visible depth when quiescent of 100 ft. It throws up its main column of water to 60 ft. or more, but a thinner spout rising from its apex ascends to a height of 250 ft. above the ground level. The explosions attending the ejection of hot water are preceded by clouds of steam which rush up to a maximum height of 500 ft.

The largest geyser in Iceland is the Great Geyser, which ejects a column of hot water, with loud explosions, sometimes to a height of over 100 ft. The eruption ends in a column of steam which shoots up with terrific force and a thunderous noise. Non-eruptive hot springs are met with practically throughout the island. In the volcanic areas sulphur springs and boiling mud lakes are common. All these phenomena are due to the operation of common underground forces.

(11) Maximum Height of natural 'Earth Pillars' 400 ft.

Note.—These are formed by the accumulation of soft earth and other materials washed away by rain. The highest are found in the Sawatch region (in Colorado, U.S.A.) —(*Negretti & Zambra*)

(12) World's Tallest Tree—the *Eucalyptus Amygdalina*, the mammoth Gum Tree of Australia } 480 ft.

Note.—Trees of this phenomenal height have been felled. They were 100 ft. in circumference near the stem. The *Eucalyptus Gigantea*, another species of the Eucalyptus, and the *Sequoia Gigantea* or *Wellingtonia*, the Big Tree of California, though not as tall, are other trees which grow to great heights. The Sequoia is a magnificent genus of evergreen coniferous trees, like the pine and the cypress. The tallest, called 'The Beauty of the Forest', is in Calaveras County and is 327 ft. high. We are told by Pouchet that at

San Francisco a piano was placed and a ball given to more than twenty persons on the stump of a Wellingtonia which had been brought there!

(13) Elevation of the World's Largest Fresh-water Lake—Lake Superior, Canada } 602 ft.

Note.—Its length is 383 miles, maximum breadth 160 miles and greatest depth 1,180 ft.

(14) Height which Sand Dunes or Sand Hills have been found to reach } 800 ft.

Note

These are hillocks of blown sand which skirt the coasts of Holland, England, Spain, Java, Peru and other countries. They are also formed on windward coasts of large inland lakes having sandy shores and in desert areas like Gobi, Takla-Makan, Eastern Sindh, Arabia and Sahara. When sand-storms break, the sand rises with great force and often forms numerous hillocks with passages between of varying width. The average height of dunes on shores is 50 to 60 ft. On the south coast of Java they are 50 ft. in height and 300 to 1,600 ft. in breadth. Dunes sometimes reach considerably greater heights and on the coast of Holland they occasionally rise to 260 ft. In the Takla-Makan desert and in the sandy wastes in the interior of Australia they are often 200 ft. high. The world's record, however, is held by the San Luis Valley of South Central Colorado in the United States of America, a country which contains large desert tracts. In this valley the dunes sometimes attain heights of 700 to 800 ft. above the surrounding land levels. In the districts of Thar Parkar and Sukkur and the eastern portions of Khairpur State in Sindh, the desert tracts, known as the Registan, consist almost entirely of ranges of sand-hills, picturesque owing to their bold outlines, some of these hillocks being fairly well wooded.

A well-known phenomenon of the desert with its boundless sun-baked wastes is the mirage, an optical illusion often seen by travellers. It is caused by the refraction of light through contiguous strata of air of different densities or temperatures. This refraction frequently produces a visual effect similar to that of direct reflection. Sometimes the mirage assumes the appearance of a sheet of water reflecting the shadows of objects within and around the plain, and

deceives the thirsty traveller. A mirage has also the effect of making a distant oasis with its palm trees appear to be close by. Even the trained eye of the Bedouin is sometimes deceived by this phenomenon.

Travellers often report having met with what are called 'musical sands'. Different explanations are given by writers as to the cause of this strange phenomenon. Says the *Evening News of India* of 12th August 1931 :—

'The Bertram Thomas expedition to the Empty Quarter of Arabia brought back some weird accounts of that eerie phenomenon, "musical" sands. Singing sands, laughing sands, barking sands, moaning sands—natural phenomena—are responsible for generations of fantastic travellers' tales and native superstitions of buried cities, and sinister underground populations. The "music" varies from sonorous rumblings to the high-pitched notes of a string-instrument. Authorities differ as to the cause. Some hold that millions of grains of sand of the same size, in regular impact, produce the sound waves, audible as uncanny, supernatural voices of space. Others, that sand grains are coated with salts, which form a film after the evaporation of water. As the grains rub together, the film produces a sound comparable to the action of resin on the bow of a violin. Singing beaches are more common than singing dunes. Of the former there are some 74 in America. There are laughing sands in South Africa, rumbling sands in Chile, moaning sand dunes in the Western Sahara between Timbuctoo and Morocco, musical dunes in the Libyan Desert, and barking sands in Kauai, one of the Hawaii Islands. Singing beaches perform only when the sand is disturbed, but the strange voices of the desert dunes charm or terrorize, as the case may be, in moments of the most impressive stillness.'

It is said that 'musical sand' is composed almost wholly of clean rounded particles of quartz, and the more rounded the grains as is the case with the desert sands, the finer is the music sent forth when wind causes them to rub together. The only 'singing sands' we have heard of in Asia are those found in China; in Europe those in Eigg Island, a small island west of Invernessshire in Scotland; and in America those of Far Rockaway in Long Island near New York.

(15) Average Elevation of Australia ... ... 822 ft.

Note.—This means that if the surface of this continent were reduced to a uniform level, its height above the sea would be 822 ft.

(16) Vertical Height or Height above the pool of the Gersappa Falls, India } 830 ft.

Note

A considerable part of the material for this Note is drawn from the *District Gazetteer, Kanara*, Bombay Presidency, 1883. These falls form the highest cataracts in Asia and fifth highest in the world. They are situated in the midst of dense evergreen forest on the frontier between Mysore State and the British District of North Kanara. From a background of richly wooded hills the picturesque river Shiravati meanders southward shining like molten silver, until near the site of the falls it is divided into four distinct streams by huge masses of rock. These streams, after flowing to short distances, plunge into an abyss about 230 ft. broad and 960 ft. deep. The pool below which receives this stupendous volume of water is 130 ft. deep, so that the falls have a vertical height of 830 ft. The principal cataract called the Raja tumbles sheer over the cliff as a vast turbid torrent until it disappears about 300 feet below in a sea of spray. About a furlong and a half to the left is the Roarer, so named on account of the furious turmoil that accompanies its descent. After a short course down a precipitous channel, its waters are caught in a basin and from there rush along a sloping wall of rock until they develop a momentum so great that the cataract continues its raging career for some 50 feet across empty space on leaving the lower edge of the precipice and unites with the Raja, the two great falls thus assuming the form of a capital K without the lower arm. A little over a furlong to the left of the Roarer is the third fall called the Rocket. Tumbling straight into the chasm for about 100 feet on to a projecting tongue of rock, this cataract sweeps downward in a smooth, graceful curve, ejecting glistening jets of spray and sheets of foam. Some 500 feet to the left of this beautiful cascade is the fourth and last fall, La Dame Blanche or White Lady. Unlike its sisters it descends gently down the cliff throughout its career 'like folds of silver gauze shaken by giant hands'.

At the height of the rains the four cataracts unite into one magnificent and gigantic column of water, nearly 2,200 feet wide. Gersappa then becomes the broadest waterfall in the world, since the width of Niagara, as has been seen, is broken by an island. It was roughly estimated by Captain Newbold who visited the Gersappa Falls in August 1845, that at this time of the year nearly 1,200 tons of water were being hurled over the cliff every second—about one

ninth the quantity of downpour at Niagara. The thunders of the cataract which seem to shake the surrounding region are heard for miles around in this season.

The most impressive view of the abyss and of the falls in their descent is that afforded from the top of a rock which projects a little from the edge of the cliff near the Raja. Here the visitor lies down as a measure of safety and gazes into the dizzy abyss. The greater part of it is shrouded in the deepest gloom. We cannot do better than reproduce Newbold's description of the sight below :—

> 'I lay on this shelf and drew myself to its edge, and as I stretched my head over the brink, a sight burst on me which I shall never forget. I have since looked down the fuming and sulphurous craters of Etna and Vesuvius, but have never experienced the feelings which overwhelmed me in the first downward gaze into the abyss at Gersappa. One might gaze for ever into that seething chasm where the mighty mass of the Shiravati's waters ceaselessly buries itself in a mist-shrouded grave.'

The present writer had the thrill of witnessing a remarkable phenomenon at these falls in December of a certain year. As he was gazing from his station near the brink of the precipice into the dark depths of this yawning abyss, the sky was suddenly overcast and a heavy shower of rain followed. On its cessation a sea of mist rose from the chasm and rapidly enveloped the whole area around. For a few minutes, wherever he turned his eyes he could see nothing but white clouds—clouds around him as well as at his feet, and with the clouds also overhead he felt as if he had been suddenly transported into the heart of cloudland high above the earth. With the reappearance of the sun soon after, the mists gradually melted away and then followed a gorgeous rainbow which spanned the gleaming columns of the four great falls.

On a sunny afternoon during the rains will be seen here a torrent-bow, a similar arch of prismatic colours formed above the spray of the waters by the refraction and reflection of sunlight. The phenomenon is described in another connection by Tennyson, who could as well have penned the lines in reference to these falls :—

> 'From these four jets four currents in one swell
> Across the mountain stream'd below
> In misty folds, that floating as they fell
> Lit up a torrent-bow.'

The din and turmoil, the clouds of spray that rise from the abyss, the sheets of foam thrown up by the turbulent waters, all

these give the impression of powers of darkness being incessantly at work in the depths below. Byron's graphic description of the Cataract of Velino could aptly apply to the Falls of Gersappa :—

'The roar of waters !—from the headlong height
Velino cleaves the wave-worn precipice ;
The fall of waters ! rapid as the light
The flashing mass foams shaking the abyss ;
The hell of waters ! where they howl and hiss,
And boil in endless torture ; while the sweat
Of their great agony, wrung out from this
Their Phlegethon, curls round the rocks of jet
And mounts in spray the skies, and thence again
Returns in an unceasing shower.'

The petrological formations of Shiravati's bed and of the area of the falls are of the metamorphic type, consisting of gneiss and several varieties of schist of underground origin embedded with bisulphide of iron.

Owing to the increasing demand for electricity in its territory, the bordering State of Mysore has a big electric power generation scheme at these falls. The Durbar in consultation with the Bombay Government has completed arrangements for preliminary surveys and gauging operations in connection with this project. It is estimated that if hydro-electric power is generated from the Gersappa Falls, an output of 80,000 horse-power can be developed with a storage reservoir of about 42 billion cubic feet capacity.

(17) Average Elevation of the Surface of Europe 985 ft.

(18) Height (above ground) of Fracto-Nimbus Clouds, popularly known as 'scuds' } 300–1,000 ft.

Note.—These are loose vapoury clouds detached from a rain-cloud and drifting rapidly. They form only when a strong wind is blowing.

(19) World's Highest Suspension Bridge —the bridge that spans the Royal Gorge of the Arkansas River, U.S.A. } 1,053 ft.

Note.—It is built 1,053 ft. above the floor of the chasm and serves as an approach to several recent additions to the new National Park of Colorado.

(20) Average Elevation of South America ... 1,200 ft.

(21) World's Tallest Building—the Empire State Building, New York } 1,252 ft.

The building was opened in May 1931. Its total cost of construction amounts to over £5,000,000. It has 102 storeys, with a mooring mast for small dirigibles 200 ft. above the roof. At the top of the mast is a chamber fitted up as a lighthouse. Four beams of white light visible for upwards of 50 miles at sea and able to pierce an ordinary fog radiate from it. A second signal displays a ball of light from which six beams radiate. In daytime, an observer on the top of this lighthouse would, in clear weather, command a horizon of more than 40 miles. The limit set for skyscrapers by the American Institution of Steel Construction is 2,000 ft. There are to-day nearly 400 skyscrapers—more than 20 storeys high—in the United States of America, half of them being in New York alone.

Here are some other tall structures in the world:—

		Height in feet	*Number of Storeys*
(1)	Bōl Gombāz, Bijapur, India	198	1

N.B.—This is the famous tomb built by Sultan Mahomed (1626-1656) as the last resting place for himself and his family. The building is crowned by a massive dome, the largest in the world, with a diameter of 124 ft. The height of the dome from its base is 90 ft. Its inner apex is 175 ft. above the floor of the building, and as the dome is at this place 23 ft. thick, the total height of the building comes to 198 ft.

		Height in feet	*Number of Storeys*
(2)	Tungchow Pagoda, China About	200	13
(3)	Kutab Minār, Delhi, India	238	5
(4)	Ile Vierge Lighthouse, Finistère, Brittany, France	247	
(5)	Tallest Minaret in Cairo, Egypt	280	21
(6)	St. Peter's Cathedral, Rome	333	25
(7)	St. Paul's Cathedral, London	365	28
(8)	Campanile (Bell-tower of the church), Cremona, Italy	396	31

N. B.—Erected in 1261-84. In the third storey is an enormous astronomical or astrological clock.

		Height in feet	*Number of Storeys*
(9)	Great Pyramid, Gizeh, Egypt	451	34

N. B.—At the base this monument is 700 ft. long. It was erected about 3000 B. C. and is even to-day regarded as a marvel of architecture and engineering.

		Height in feet	Number of Storeys
(10)	Cathedral of Strasbourg, Bas-Rhin, France	465	
(11)	Cathedral of Cologne, Germany	512	40

N. B.—This is the world's finest example of Gothic architecture. It took six centuries to build, the foundation being laid in the 13th century.

(12)	Washington Monument	555	42
(13)	Woolworth Tower, New York	792	58
(14)	Eiffel Tower, Paris	984	3

N. B.—It is the world's tallest tower and is named after Alexandre Gustave Eiffel, a famous French engineer, who constructed it in 1887-89. The first storey is 200 ft. above the ground floor, and the second 700 ft. above the first. 84 ft. above the second storey is the sky chamber in which Eiffel used to live out of a love of fresh air. Lifts, for which a small fee is charged, are now available to carry visitors to the top. Frequent examinations of the hydraulic bases of this tower have shown the foundations to be still as solid as when they were first laid.

(15)	Chrysler Building, New York	1,030	177

(22) Average Elevation of North America ... 1,350 ft.

(23) Average Elevation of the Earth's entire Land Surface ... 1,440 ft.

(24) Elevation of the World's Deepest Lake—Lake Baikal, Siberia ... 1,516 ft.

Note.—Its length is 421 miles and breadth 15 to 46 miles. Its coast-line is 1,375 miles long. The greatest depth of the lake is 4,993 ft. The bed here is thus 3,477 ft. below sea level. The lake is connected with the city of Irkutsk to the west by the Trans-Siberian Railway. Mineral springs and hot alkaline springs exist at various places round its shores. It is surrounded by granite cliffs which often rise sheer from the water's edge in lofty walls, but they do not shelter the lake from the winds. Sudden storms arise and lash its waters into huge waves, and at such times it presents the appearance of a sea. In fact, owing to its enormous depth and the presence of seals in its waters, it is considered probable that in the remote ages the lake formed a gulf of the sea, though geologists hold that it was at no time connected with the Arctic Ocean. The belief that it was originally probably a part of the sea is supported by the geological theory explained under Item 122.

Near the northern shore of the lake lies the island of Olkhon, which is inhabited. With an area of 32 miles by 10 miles, it is one of the largest lake-

islands in the world. The deepest sounding taken was at a spot close to this island. The water of the lake is extraordinarily clear. The surface is frozen from January till the second half of May with ice over 3 feet thick and in winter the lake is crossed on sledges.

(25)	Average Elevation of Africa	1,600 ft.
(26)	Average Elevation of Asia	1,600 ft.
(27)	India's Holy Springs of Invisible, Inflammable Gas	1,155 & 1,958 ft.

Note

The lower of these (1,155 ft.) are situated at Sitakund, Chittagong District, Bengal, which contains a number of temples. Sitakund lies on the top of a range of hills and is a well-known place of pilgrimage visited by people from all parts of the Province. An interesting feature of the locality is the inflammable gas which issues slowly from crevices in the rocks.

The other springs (1,958 ft.) lie in a temple in the Beas valley in the Kangra District of the Punjab. It is an important place of pilgrimage. Sir Louis Dane, a former Lieut.-Governor of the Province, who visited it when he was Assistant Commissioner of the district, found there devotees from so distant a place as Hyderabad (Deccan). The temple is built over jets of a natural gas which is combustible. In the interior is a square pit about 3 ft. deep with a pathway around. In the middle of the pit the rock is slightly hollowed out about the main fissure, and when a light is applied here, the gas catches fire. It escapes at many other points from the crevices in the rocky walls of the pit, but it collects very slowly. The attendant *Pujāris* or worshippers, when there is a large influx of pilgrims, keep up the fire with ghee (clarified butter). The flaming fissure is believed to be the fiery mouth of a goddess, and hence the name Jwālāmukhi ('She of the Flaming Mouth'), whose headless body is said to be in another local temple. This shrine is mentioned in the Māṇasa Khanda of the Skanda Purāṇa, the 13th of the 18 Purāṇas (religious books of the Hindus), which contains a dialogue between King Dhanvantari of Kāshi (Benares) and the sage Dattātriya. Replying to a question by the king regarding the route by which a pilgrim should make the return journey from

the sacred lake of Mānasarōvar, the sage names, among the places to be visited on the way, Jwālā Tirtha (identified as Jwālāmukhi) where the pilgrim is required to worship the sacred fire and bathe in the Padmāvati, thus completing the pilgrimage. The dialogue between the king and the sage forms part of a long story narrated by Sūta, a pupil of the great sage Vyāsa, to King Janamējaya, the son of Parikshiti. All this shows that these sacred springs are of hoary antiquity.

In the vicinity of Jwālāmukhi are six hot mineral springs. Their water is impregnated with sodium chloride (common salt) and potassium iodide.

Natural gas like that at Sitakund and Jwālāmukhi generally occurs in petroleum-bearing areas such as those of Assam, Burma and Java. The oil-bearing region nearest to Jwālāmukhi is Khaur near Rāwalpindi, a place also in the Punjab situated some 250 miles away. The gas, though invisible, possesses a perceptible odour. Our ancients therefore must have discovered the Jwālāmukhi springs in the course of geographical exploration.

Java contains a similar example in the gas-fountains or holy fires of Melati Derat. These have a historical significance. In utilizing them for lighting holy fires the Hindus who colonized the island in olden times were evidently influenced by the example of Jwālāmukhi.

The gas is more widely distributed than oil. There are numerous places where it has been found but no petroleum occurs in the immediate vicinity. Like petroleum itself, the gas is for the most part composed of hydrocarbons. In the Indian and Javan holy springs it oozes out slowly and in small quantities, which accounts for the absence of any serious fire hazard around them. In the fields of Oklahoma, Southern California, Texas and other great oil centres in America, the gas occurs in a compressed state and comes out in considerable quantities, often in the shape of giant gushers spouting oil high into the air. In the rich field of eastern Texas the buried gas is so compressed that its pressure not only lifts the oil to the surface but is used to drive the pumps. But as the gas is highly inflammable, the exhaust gas is burned and tongues of flame as long as 30 feet dart forth from the exhaust. Almost up to the

point whence the flame starts, the exhaust-pipes are coated with ice and frost by the chilling effect of the rapidly expanding gas.

A remarkable instance of how compressed natural gas sometimes reveals its presence in a startling manner is related in *Popular Science Monthly* of July 1932. A citizen of Los Angeles (California) recently planned to build a house on a piece of land at one corner of which was a depression about 10 feet across. This depression was the site of an oil-well abandoned long ago. The work of construction was about to begin, when one morning a deafening outburst aroused the neighbourhood. With a terrific roar a column of mud and water, propelled by a heavy accumulation of natural gas, rose from the depression and shot up 150 feet into the air. For four days the mud rain continued, until at last the pressure subsided.

According to the organic theory of the origin of petroleum, which finds acceptance with most geologists to-day, the components of the hydrocarbons occurring within the earth's crust were generated from the remains of microscopic organisms of plants and animals of marine origin embedded in sedimentary formations. In view of this theory and the one explained in some detail under Item 122, the regions in which Jwālāmukhi and Sitakund are situated must have originally lain under the ocean.

(28) The remarkable Chillan Baths, Chile, South America } 2,050 ft.

Note.—These are mineral springs—sulphurous, ferruginous, alkaline and saline, both ice-cold and boiling springs lying in close proximity of one another. In India too there are similar examples, the cold and hot springs lying close to each other and showing marked difference in their temperatures. One group is situated at the sacred place of Gaurikunda on the Mandākini river between the Himalayan shrines of Triyugi Narayan and Kédarnath. One October day at 5 p.m., when the temperature of the surrounding air was 18° C. (64° F.) and that of the river close by 11° C. (52° F.), the temperature of one of the springs was 23° C. (74° F.) and of the other, lying within 50 yards of the first, 53° C. (128° F.). Another similar group in the Himalayan region is dealt with later on.

A remarkable group of sulphur springs lies in the Birbhum district of Bengal. There are 5 or 6 hot springs in the Bakréshwar stream about 8 miles from Suri and, separated from them by only a few feet, are a number of cold springs. Near Bakréshwar there is another spring called Suryakunda, which is the hottest in the Province. Its temperature is 88° C. (190° F.).

It is stated that an egg can be boiled in it, though not rice. Suryakunda is mentioned, among other springs, in the Mānasa Khanda of the Skanda Purāna. A few paces from it lies a cold spring.

The vicinity of Pandeglang in Java is another place in Asia noted for its hot and cold sulphurous springs.

(29) Vertical Height of the World's Highest Waterfall—the Cerosoli Cascade in the Alps ... 2,400 ft.

Note.—This information is taken from the *Bombay Gazetteer, Kanara,* Part II, p. 285.

(30) Base of Stratus Clouds ... ... 2,500 ft.

Note.—These are low clouds arranged in dense, uniform, horizontal bands or layers. The stratus is also known as the fall or night cloud.

(31) Record Height at which Cricket's Chirp has been heard ... 2,500 ft.

Note.—The climbing power of terrestrial sounds has been ascertained by means of balloon ascents, the ground staff co-operating where necessary. The present item and similar others which follow later show the results of these observations.

(32) Height (Vertical Thickness) of the thickest Valley Glaciers ... 3,000 ft.

Note

The moisture which falls from the atmosphere upon those parts of the higher mountains that lie above the line of perpetual snow settles there as snow. This snow later on becomes an immense sheet with the yearly accretions, but while its upper portions remain loose and practically unchanged, the lower layers are compressed into a substance called *névé* or *firn*, which consists of snow as well as ice. Partly under the pressure of the masses above and partly owing to the water released by the slight melting of their surface snow under atmospheric heat, the lower layers become more and more compact and ultimately solidify into ice. These formations creep downwards from the higher mountain valleys to lower ones in long protruding masses known as *glaciers*. Glaciers are rivers of ice, and like rivers they often have tributaries. As they travel down the snow-line, they gradually melt under the influence of atmospheric heat, produce mountain torrents and thus supply the water that goes to form rivers. They cut deep grooves in the solid

rock in their passage. In the course of their descent they carry fragments of stone that fall on them from the rocky walls of the valleys down which they move. Sometimes the materials carried along include boulders as big as houses. The debris which thus accumulates at the sides of a glacier forms what is termed a *lateral moraine.* Two glaciers uniting together merge their adjacent lateral moraines to constitute a *medial moraine.* The debris which is ultimately deposited in the valleys at the lower extremity of the glacier forms a semi-circular heap, which is called a *terminal moraine.* As a glacier crawls along an irregular or steep channel, deep clefts are often formed in it. They are frequently very broad and always terminate at the base of the glacier itself. These are called *crevasses.* They may be either transverse or longitudinal according as they cut the glacier across or in the direction in which it moves. As the glacier passes down a sharp incline or travels along a highly uneven bed, its breakage also gives rise, as in the Alps, to pyramidal masses of ice, 20 to 50 ft. high, called *séracs,* which are often found shooting up from the surface of the glacier in large numbers. On the Rongbuk Glacier, which has to be crossed by mountaineers in climbing Everest from the Tibetan side, some of these pinnacles are as high as 100 ft. They thrust themselves up from the boulders which cover a great part of the glacier. These sharp-edged peaks of ice, broad open crevasses, and crevasses hidden by treacherous snow-roofs present dangerous obstacles to mountaineers endeavouring to cross such a glacier. Icy water often collects at the bottom of the crevasses, and with their solid chilling walls and intensely cold air these abysses form Nature's gigantic refrigerators. Explorers have occasionally been engulfed in the Alpine crevasses, and years after, their bodies, lifelike and in perfect preservation, have often been given up by the ice in its slow funeral march down the mountain side. In one case a whole expedition perished in a crevasse in Mont Blanc, and their bodies were surrendered by the glacier twenty years later, wonderfully preserved.

We may now mention some of the biggest glaciers in the world. Of the Alpine glaciers, which are nearly 2,000 in number, the largest are 10 to 15 miles long, 1 to 2½ miles broad, and 100 to 600 ft. thick or more. The thickness of one of them, the Aar Glacier, has been estimated at 1,510 ft. The majority of the glaciers of the

Himalayas are 2 to 3 miles long, though the range contains some which are many times more extensive. But the Karakoram Range is the nursery of the largest valley glaciers in the Eastern Hemisphere. In his *Geology of India*, Professor D. N. Wadia mentions nine huge glaciers of these two regions, two of which belong to the Sikkim Himalayas, two to the Kumaon Himalayas and five to the Karakoram. The Gangōtri Glacier, which lies in the Kumaon Himalayas, is 16 miles in length, while the Karakoram giants are from 24 to 39 miles long, the two largest being the Bāltoro and the Biafo Glaciers whose respective lengths are 36 and 39 miles. Another writer states that in the Remo Glacier, one of the Karakoram streams which has tributaries, situated about 50 miles south-east of the Bāltoro Glacier, 15 distinct moraines have been counted. The Karakoram glaciers lie in the Baltistan Province of Kashmir State.

Some 5 miles south of the Remo Glacier lies a smaller one, the Khumdan Glacier. The mass of this latter lying at a right angle to the bed of the Shyok river (a mountain tributary of the Indus fed by the Remo Glacier) 8 miles below the village of Yapchan, pushes its snout into the river-bed. Once in two years or so, the glacier in its slow movement across the bed entirely blocks the valley with a stupendous mass of ice which effectually 'dams' the river. This part of the glacier has therefore come to be known as the Shyok Dam. Competent observers have estimated it to be over 1,000 yds. long, a mile broad and 500 ft. high. As thaw sets in, the level of the water behind this natural barrier rises and a huge lake is formed with a superficial area of nearly 25 sq. miles and an average depth of 175 ft. At last the numerous trickles below the glacier and the enormous pressure of the pent-up waters, combined with the action of warmer weather, cause the glacial wall to burst. It is said that its bursting can be heard for a distance of over 10 miles. The sudden release of the accumulated waters transforms the river into a raging torrent which goes to swell the Indus, itself already swollen owing to the thaw which begins about this time of the year (July). If the Punjab rivers at this time happened to be swollen with abnormal rains and their surplus waters united with those of the Shyok in the Indus above Sindh, a mighty flood would result and seriously affect the river-plains along the whole course of the Indus in this Province. That the burst of a glacial dam in

Central Kashmir should under certain conditions affect areas over a length of 1,500 miles, is remarkable. The periodical floods caused by the formation and bursting of this great ice barrier have resulted in considerable havoc in the past. In 1833 the flood rushed down the Shyok valley destroying every village in its path. The most recent floods are those which occurred in 1926, 1929 and July 1932. In the flood of 1929, the most serious of these, the ice wall had only cracked, letting the water out by degrees, and yet the gauge at Skārdu, a village at the junction of the Shyok and the Indus, rose from 17 ft. to 42 ft., and the Attock gauge from 27·5 ft. to 56 ft. Whole villages had to be evacuated. Nowadays much of the danger is averted by timely measures. As soon as the dam is formed, guards are placed to watch it, and constant reports keep the authorities informed of the situation all along the courses of the rivers as far as Karachi. The aeroplanes of the Royal Air Force at Peshawar also help, if necessary, by reconnoitring the Shyok river and giving timely information of the advance of the flood.

The higher parts of the Alaskan Range in North America are the gathering grounds for some of the largest valley glaciers in the world. Five or more of these immense tongues of ice are 2 to 4 miles broad and 30 to 50 miles long. But still bigger ones are found in Greenland. They are the biggest and thickest of valley glaciers in the world. They are 2,000–3,000 ft. deep, some being upwards of 50 miles in length. From the main valleys they push out seaward until at last with a deafening crash the advancing masses plunge into the ocean in huge cataracts of snowy fragments to form icebergs. The impact with the sea surface is as startling as a thunder-clap, and the rolling away of the high-crested seas, followed by the rocking to and fro of the prodigious masses in the effort to regain their equilibrium is a most impressive spectacle. Greenland is really a subcontinent covering 827,275 sq. miles, an area about equal to the combined areas of England, France, Spain, Germany, Poland and Hungary. Its name is highly misleading. Instead of being an island carpeted with vegetation it is a gigantic bowl of ice—a vast bleak, desolate region, about 86 per cent of whose area is covered with a shield of ice. Beyond the main valleys the Greenland ice-cap increases in depth until at its centre it attains a thickness of 8,850 ft.

About three-fifths of the continent of Antarctica, whose area is 5,400,000 sq. miles, is covered by an enormous ice-sheet with a thickness of over 10,000 ft. around the centre. The glaciers of Antarctica are called 'continental glaciers'. Geologists often include in this category the glaciers of Greenland also.

Of late years glaciologists have been employing the acoustic method to ascertain the vertical thickness of glaciers which are extraordinarily thick. Sound has been found to travel in ice (at -4^{0}C. or 24·8 ^{0}F.) at the high velocity of 3,232 metres or about 10,600 ft. a second. The depth of the central part of the Greenland ice-cap was measured by means of a seismograph, the instrument which records earthquakes. Vibrations were artificially set up in the earth by dynamite explosions and measured by the seismograph, and the time taken by the sound waves to reach the observer was recorded. Another set of waves passed through the ice to the ground below and were reflected back to the instrument. By checking the difference in the respective lengths of time taken by the sound waves to travel, the angle of travel of these waves was measured and the vertical thickness of the ice calculated.

The Glacial Epoch or Ice Age has for a long time been defined as that period in the later Tertiary Era in the geologic scale of time during which both the Arctic regions and the Temperate regions down to the parallel of 52^{0} N. latitude were covered with a sheet of ice which formed a polar ice-cap. Geologists have now come to the conclusion that there have been several Ice Ages in the earth's history and that the last Ice Age commenced in the post-Tertiary or Quaternary period and is now only about half over in spite of scorching summers. They remark that about 700,000 years ago the great ice-sheets in the polar regions covered double the present area. They have been noticing that these vast masses have been melting, though very slowly, and pouring their waters into the seas. It is estimated that the glacial sheets that cover the Arctic and Antarctic regions are now about 6 million sq. miles in area. The ice-sheet on Greenland alone covers an extent of over 700,000 sq. miles, and can provide enough water to produce a sea 840 miles square and a mile deep. Similarly, the ice-pall over Antarctica can supply a volume of water sufficient to form an ocean 1,800 miles square and a mile deep! The rest of the polar ice covers an area of 2,060,000 sq.

miles. Scientists have been calculating what the extent of rise will be in the level of the sea the world over when all the polar ice has melted. Dr. W. J. Humphreys of the United States Weather Bureau, in the light of the information gathered in the Antarctic regions by the Byrd expedition and in Greenland by the late Professor Alfred Wegener and his party, estimates that this rise will be 151 ft. Under such conditions changes must inevitably occur in the earth's aspect and climate. Geologists, physicists and meteorologists have recently considered how the changes are already taking place and what the ultimate result will be. A summary of the views expressed is before us:—

'The earth is steadily growing warmer. As all the ice at the two Poles melts, a stupendous volume of water will be released. .... Such floods are nothing new, as we see by the marine fossils found on the tops of the Rockies, Andes and other mountain ranges. So, within 30,000 or 40,000 years there will be another deluge. Salt water will sweep over the continents, leaving only the higher land dry. Holland will be inundated. Fish will swim in Buckingham Palace and Westminster Abbey, for most of England will lie beneath the waves. The Desert of Sahara will be a great inland sea. What is now New York will be marked by the upper stories and towers of the taller skyscrapers as they jut out of the water. In an inundation which would thus change geography and which would be accompanied by a rise in temperature, the climate would return to what it was when dinosaurs roamed the earth and dense jungles of dank, gigantic fern grew in what are now Pennsylvania and Canada. Palms and alligators would flourish at the Poles as they did millions of years ago.

'What will become of man if climatic conditions are thus changed? Ice sheets in high latitudes produce strong contrasts in temperatures between the polar and equatorial regions. Winds, storms, weather that changes from day to day are the result. Man flourishes under such conditions. If the Torrid Zone were to become even more torrid than it is, and if what are now frozen tracts around the North and South Poles are to bear sub-tropical life, man's food supply will not be what it is now. Professor G. C. Simpson of the British Meteorological Office has advanced the theory that Chellean, Mousterian and other races of men that once flourished in Southern Europe were wiped out because the climate changed and inedible vermin took the place of the animals that were hunted. No one can tell what may happen if a new carboniferous era should follow the warming of the earth. Man is about as old as the present Ice Age. It is a question if he will survive it.'

Having given an idea of the extent of ice present in the polar regions, we may now try to ascertain its approximate weight on the basis of Humphreys' estimate, already mentioned, of the rise in

the level of the seas when all the polar ice has melted. This ice will yield a layer of water spread over the whole oceanic area of the earth to a depth of 151 ft. and to lesser depths over the coastal plains. We know the total oceanic area to be 141,038,687 sq. miles or $141{,}038{,}687 \times 5280^2$ sq. ft. Now a cubic foot of pure water at 4^0 C. ($39{\cdot}2^0$ F.) weighs 62·4 lbs. or $\frac{62{\cdot}4}{2240}$ ton. The weight of the 151-ft. layer of fresh water over the present ocean surface will therefore amount to $141{,}038{,}687 \times 5280^2 \times 151 \times \frac{62{\cdot}4}{2240} = 16{\cdot}54$ quadrillion tons! To this has to be added the weight of the water that will be responsible for the submergence of the coastal plains. So an estimate of the order of 20 quadrillion tons, we think, can be put forward as the weight of all the polar ice on the globe.

(33) Record Height at which Locust swarms have been seen flying } 3,000 ft.

Note.—These pests have been seen flying high enough to constitute a nuisance to aeroplanes flying at ordinary altitudes. In November 1929, as the inward Indian Air Mail 'plane was flying at a height of 3,000 ft. about 100 miles from Bushire, some of these insects got in through the window of the aeroplane. About the end of November in the same year a swarm of locusts extending over a front of 25 miles swept past the city of Marrākesh, the ancient capital of Morocco, taking three hours to do so. The swarms were so dense as to darken the sky. An aeroplane was ordered to follow their movements, but it was soon beset by hordes of these insects until the pilot sprayed them with poison gas and forced masses of them to the ground. By a curious coincidence, in the same month an immense cloud of these pests passed over Ahmedabad (India), shutting out the sun and sky during the course of their flight. In *Science and Invention* of May 1931 Mr. Paul L. Hoefler, the leader of the Colorado African Expedition of 1928, gives an account of locust swarms which were seen in October of that year above the vicinity of Lake Baringo in Tanganyika. The cloud of locusts was computed to be about 150 miles long and 50 miles wide. We have come across one instance where these insects attempted a 'non-stop flight' across the ocean! Many years ago locusts were seen from a steamer in the Atlantic at least 1,200 miles away from land, in swarms so vast as to completely obscure the sky. A still better idea of the enormous numbers composing these hordes may be gathered from the fact that in the island of Cyprus 1,300 tons of locust eggs were destroyed in the year 1881.

(34) Base of Nimbus or Rain Cloud or Cumulo-Cirro-Stratus Cloud } 3,000 ft.

Note.—It is a dense layer of dark flat clouds from which rain or snow generally falls.

(35)	Greatest Height at which Frog's Croak has been heard	3,000 ft.
(36)	Top of Stratus Clouds	3,200 ft.
(37)	Greatest Height at which Sea Gulls have been seen flying	3,000–4,000 ft.
(38)	Elevation of the World's most spectacular Active Crater—Kilauea in Hawaii or Sandwich Islands, North Pacific	4,000 ft.

Note.—This crater is 9 miles in circumference with an oval pit 4¼ square miles in area lying at a depth of about 500 ft. For several decades past visible activity has been confined to a smaller inner pit, also oval in shape, measuring 3,500 ft. by 3,000 ft. and 1,300 ft. deep. It is named Halemaumau, a native term meaning 'The House of Everlasting Burning'. In this pit lies a lake of steaming lava, 2,600 ft. long and 2,200 ft. wide—red and boiling at one extremity. Around the edge and from the midst of this lake no fewer than 51 subsidiary craters send forth jets of liquid lava, vapour or flame. For further information *vide* Chapter IV.

(39)	World's Height Record for a Glider or Sailplane carrying two men	4,101 ft.

Note.—This height was reached in a flight in Germany by Groenhoff on 30th July 1929. He carried a passenger with him.

A glider is an engineless aeroplane which flies only with the aid of ascending air currents which are frequently met with on hills. From his cockpit the pilot operates the rudder, tail flippers and ailerons through controls similar to those in a power-driven aeroplane. The glider is usually launched into the air at the end of a light elastic rope which is attached by a ring to a hook fastened on the nose of the machine. The crew hauling on the rope is assisted by another body of men in the rear who hold the machine down until their comrades in front develop sufficient speed in their run. At a word of command they release their hold, and the glider is catapulted into the air like a stone from a sling-shot. On reaching a height of 25 to 30 ft., the pilot releases the tow-rope by pulling a lever and then avails himself of the rising currents of air. As altitude is gained, the ability to stay up longer is increased, for air currents are more pronounced and the wind blows harder, as a rule, at higher levels.

A knowledge of air currents is essential to a pilot for successful glider flights. Hills offer good starting points, as an ascending

column of air is usually met with there on one side. Gliders are also launched from the top of great sand dunes such as those found on the Baltic coast in north-eastern Germany. Where suitable hills or sand dunes do not exist or are not easily accessible, gliders are often towed up into the air by a light aeroplane and released after a suitable height is gained. At an experimental flight a pilot in Germany has succeeded in taking to a height of 1,000 feet an 'aerial train' consisting of a 120 horse-power sporting aeroplane and four gliders in tow.

It is reported from Stuttgart that a new method of starting a glider has been employed with success at the Bubinger flying ground in Germany. The glider is placed on a kind of shoot and shot into the air by an apparatus similar to a catapult. Another interesting report, which comes from America, says that an aviator of Atlantic City, New Jersey, recently gave before a crowd of 2,000 spectators a successful demonstration of a rocket glider designed and constructed by him. In spite of an adverse wind he rose 260 ft. and attained a speed of 35 miles an hour. If the new German contrivance should be found, in the light of longer experience, safe and reliable, it would undoubtedly revolutionize glider flying everywhere.

One of the principal fascinations of glider flying is the complete absence of the noise which mars the pleasure of a flight in a motor-driven aeroplane. The pilot of a glider hears all the everyday sounds that rise from the countryside. Besides, while he is dependent upon air currents, he can often make them subject to his skill in flying, so that he can hover more or less over the same spot or rise and fall at will.

Gliding has now become a general sport in many countries, and most large cities have their Gliding Clubs. Glider flights are most popular in Germany where the science of gliding has made greater advance than in any other country.

Gliding is slowly making its way into India. The Indian Gliding Association, a body formed in Bombay in September 1931, has opened a training camp at Aundh in the Southern Maratha Country for the benefit of its members. A suitable hangar, workshops and camping conveniences have been provided by the Chief of Aundh, who is himself a Patron of the Association and is taking keen interest in its progress. The Association possesses a few

machines of the best German and American types. The materials were ordered out in the form of raw wood and metal fittings, and with the help of working plans supplied with them, the members have succeeded in constructing gliders of the most perfect and up-to-date design. The site of the camp offers great facilities for glider flights of several hours' duration, owing to the rising air currents met with in abundance in the mountainous regions of the Deccan. The main object of the Association is to create air-mindedness among the youth of the country. Training in motorless aeroplane flying is regarded as the best way developing sufficient 'air-sense' in the learner of the art to make him enter the real field of aviation.

(40) Elevation of the World's Saltiest Lake —Urumiah, Persia } 4,200 ft.

Note.—Its area is 75 miles by 30 m., and maximum depth only 45 ft. Owing to its intense saltiness no fish inhabit its waters. There is another body of water which is a fourth again as salty, *viz.*, the Karaboghaz, but it is not a lake by itself, being an offshoot or gulf of the Caspian Sea in its eastern side. It is nearly circular, and although 90 miles across, the channel by which it communicates with the parent lake is only about 150 yds. wide and 5 ft. deep.

(41) Elevation of the World's Highest-Rainfall Area—Cherrapunji, Assam, India } 4,455 ft.

Note.—Cherrapunji is a small town standing on a plateau of the Khasi Hills and overlooking the plains below. Its average rainfall per year is 458 inches, but the year 1861 broke all previous records with a total of 905 inches, of which 366 inches fell in July alone. The hill at this place forms a sudden barrier to the south-west monsoon blowing across the flooded areas of Eastern Bengal and the Sylhet district of Assam. The air, surcharged with moisture, cools and torrential rains follow. The plateau, being broken by gorges on either side, is completely surrounded by cooling vapour. Vast blocks of stone are rolled along with a tremendous crash by the rain-water torrents. It is reported that on one occasion a 350-ton boulder was dislodged and carried off to a distance of more than 100 yards in a single night!

At the other end of the scale in India comes Upper Sindh Frontier District with an average rainfall of less than 3 inches a year. The world's record, however, in this respect is held by the coastal zone of Peru in South America, a region about 1,300 miles long and 40 to 100 miles broad. Here there is no rain whatever, and on the western slopes of the Peruvian Andes below the levels of 4,000 to 6,000 ft. and along a distance of nearly 900 miles south to north up to 8° S. lat., the yearly rainfall amounts to less than 2 inches. The reason is that the westward movement of the rain-bearing

winds to the coastal zone of Peru is effectually barred by the great mountain heights and they are forced to rise, with the result that their load of moisture is cooled and deposited east of the mountain and on its eastern slopes. The annual rainfall on these slopes amounts to about 150 inches. The town of Debundscha at the foot of the Cameroon Peak in French Equatorial Africa, perhaps takes the second place after Cherrapunji, with its average yearly rainfall of 369 inches.

(42) Base of Cumulus Clouds ... ... 4,600 ft.

Note.—These clouds appear in dense masses of a nearly hemispherical form above, but usually flat below, often piled one upon another, forming great clouds and presenting the appearance of gigantic mountains crowned with snow. They often afford rain and thunder gusts and are common in summer. Their thickness is about 1,300 ft. The Cumulus is popularly called Woolpack or Cauliflower cloud.

Sensations and Experiences during Flight at Moderate Heights

A peculiar sensation to which novices are sometimes liable in mid-air is 'air-sickness', a malady akin to sea-sickness. During flights at altitudes of 4,000-5,000 ft., airmen sometimes meet with a strange experience. While flying over land through a rain-cloud, they often see for hours together neither earth nor sky, and while flying across the ocean between two layers of clouds during strong air disturbances, neither sea nor sky!

The experiences of aviators who have flown near the Poles are no less interesting. The Polar expedition led by Commander Byrd discovered in the course of their flights that, when the ground was buried in snow and the sky was overcast so that the diffused light threw no shadows, the horizon disappeared from the view, and sky, ground and snow all looked alike, making it almost impossible for the pilot to find out where the ground lay beneath him. Polar fliers therefore guard against this danger by flying low in winter, never losing sight of the ground. The scientists who joined Byrd's expedition had weird experiences to relate. 'Small objects look larger,' they say, 'one man mistook a shoe for a seal. As there is no visible horizon, everything appears distorted. The sun looks

like a spin-wheel, and everything seems unreal and unearthly. Mirages are everywhere.'

(43) Greatest Height at which the Crowing of Roosters, the Ringing of Church Bells and under certain conditions Human Shouts have been heard ... Nearly 5,280 ft. = 1 mile

(44) Elevation of Asia's Hottest Springs—the group at Manikarn in Kulu, Kangra District, Punjab, India ... 5,587 ft.

Note.—Manikarn is a place of pilgrimage on the right bank of the river Parbati and contains 7 or 8 temples. It lies amidst high snow-capped mountains. There are several hot springs in the village, says Surgeon-General Balfour in his *Cyclopaedia of India, Eastern and Southern Asia,* 'three or four of which boil furiously. The latter issue out of rocks near the edge of the river. Dense steam rises out of them in considerable volumes, heating the air all around, and absolutely darkening the path for a few yards, and the heat is very distressing. All the inhabitants of Manikarn cook their food in these boiling springs, and wood is never used by them for culinary purposes.' Though the temperature of these springs is not mentioned, they are probably the hottest springs in Asia.

In the temple of Ramachandra at this place there is 'a jet of steam and water rising 8 to 10 ft. high with a loud rushing noise and throwing up small round polished granite pebbles or *manis*', and hence the name Manikarn.

(45) Base of Cumulo-Nimbus Clouds......4,600-6,000 ft.

Note.—These are great heaps of cloud towering like mountains, usually having a thin fibrous top and a mass of cloud similar to the Nimbus at the base. As they accompany every thunder-storm, they are also called Thunder-Clouds. Rain or snow falls from their base.

(46) Height which Sand-storms have been found to reach ... 6,000 ft.

Note.—During such a storm in July 1929 the sand rushed in through the windows of an inward Indian Air Mail Aeroplane flying at this height over the desert tract between Alexandria and Baghdad. The rising sand is naturally accompanied by vast quantities of dust. But as dust is the lighter of the two, it rises considerably higher, so that the upper region of a sand-storm is composed wholly of dust. An airman, therefore, flying just high enough to avoid a sand-storm, runs into a dust-storm. The aviator Capt. Neville Stack, during his flight from Blackpool (England) to Karachi in June 1932, encountered a severe dust-storm between Baghdad and Basra. For nearly 200 miles the dust rose to 12,000 ft., and he had to fly at an altitude of 14,000 ft. Sand-storms and dust-storms render the ground invisible and direction of the aeroplane difficult.

Another discomfort experienced by airmen flying over a desert in summer is the blistering heat which makes itself felt even at great heights. During Capt. Stack's flight to India he found that the great heat belt of the Iraq desert, whose temperature was 110° F. (43·3° C.), rose to 8,000 ft.

(47) Greatest Height reached by an experimental, unmanned Mail Rocket Plane } 6,000 ft.

Note.—The following brief description of this rocket 'plane and its flight appeared in the Press as a cablegram dated 15th April 1931 from Osnabruck, a town in the Prussian Province of Hanover:—

'Claimed by its inventor, an aeronautical engineer, Reinhold Tilling, to be a "real rocket plane" because it returns near its starting point, a new rocket was tried out here to-day and reached a height of 6,000 ft., where it automatically unfolded the two wings and glided to the earth without any damage. The rocket is propelled by powder. Its inventor contemplates constructing a man-carrying rocket.'

Further particulars of this remarkable machine and its flight appeared in the Calcutta newspaper *Bengalee* of 13th May 1931 as an item of news from a Berlin correspondent. It was Herr Tilling's first 'model passenger rocket', about 5 ft. long. The span of its wings when open was over 6 ft. Its hollow cylindrical body contained a rocket 2 inches in diameter and 2 ft. in length. The conical head of the rocket carried a packet of postcards. The machine began its flight from a launching pier and climbed in a steel curve with a gradually increasing speed until it developed a high velocity. At the highest point it reached, it could be seen as a tiny dark speck which would have been lost to sight but for its tail shaped like a comet's. As its speed began to slow down, the tail broke away, the wings automatically unfolded, and the machine descended in a series of graceful curves, alighting not far from its starting point. The postcards were found intact.

A model aeroplane of a new design, constructed by Tilling and driven by miniature rockets, recently made a trial flight over an island in the North Sea off the German coast.

(48) Apex of Nimbus or Rain Clouds ... 6,500 ft.

(49) The 'Benares' of Central Java ... ... 6,500 ft.

Note

In the early part of the Christian era, Hindus, mostly from the Coromandel Coast, began a migration eastwards. In the Sunda group of islands the first to receive them was Sumatra referred to by certain writers as Suvarnabhūmi ('Land of Gold'), where they introduced Hindu civilization and culture. About the 5th century a royal mission from Kashmir of the Mahāyāna school of

Buddhism visited the island and succeeded in inducing the Hindu settlers to embrace that religion which, however, figured among them more as an intermixture of Brahmanic and Buddhist cult. By the 7th century their descendants had founded a powerful Hindu-Buddhist kingdom called Shri Vijaya with its capital at Palembang. Its rulers bore the title of Maharaja, and their dynasty is known by the name of Sailéndra. The Sailéndras subsequently extended their sway to Malay Peninsula and probably to some other countries and became a great maritime power. The Chinese Buddhist traveller I-Tsang, who visited Palembang about 690, found it to be a well-developed Hindu-Buddhist seat of learning. By this time Hindu migration had spread to other islands in the group. Java appears to have been colonized by the Hindus next after Sumatra. According to tradition, a Dravidian Prince arrived in western Java about the 4th century with a few thousand followers and settled at Mataram. The Hindu kingdom of Tārumā was established soon after with its capital at Kartasura, six miles west of the modern city of Surakarta. No sculptures of this period are extant, and the only evidence of the existence of this kingdom is furnished by inscriptions of the 4th and 5th centuries.

Some scholars are inclined to believe that the colonization of Central Java was effected by the Hindu immigrants of western Java, while others hold that it was colonized direct by a stream of immigrants from the ancient Indian Province of Kalinga. Professor Himansu Bhushan Sarcar of Calcutta considers that the first Hindu settlers in this part of the island were the Shakas of Gujarat, who according to the hypothesis, had introduced Shaivism and the system of Shaka year-computation in 456 A. D. His view is partly based on the fact that the years between 654 and 682 Shaka (732 and 760 A. D.) saw the palmy days of Shaivism in Central Java.

Late in the 7th century the ruler of Shri Vijaya sent an expedition against Java, as appears from a South Indian inscription dated 686 preserved in the British Museum in London. In 778 the then Maharaja caused the first Buddhist temple in the island, that of Kalashan, to be erected in Central Java—an event which shows that by this time probably Java had been annexed by him or its ruler had become his vassal. The question arises here whether Buddhism was introduced in Java between these two dates by the Sailéndras of Sumatra or

came from India direct. Sarcar thinks that it probably went to Java from East Bengal where the Pāla sovereigns first rose into prominence in the 8th century. In later years Java saw several lesser States spring up one after another.

About 1293 four of the kingdoms in Java united and under the king Kritarājasa founded an empire with its capital at Majapahit. In that year an envoy was sent by Kublai Khan, the founder of the Mongol dynasty in China, to demand homage from the emperor of Majapahit but was sent back in disgrace. A large army was despatched to Java to avenge the affront, but after slight success it met with reverses and was forced to return with heavy loss. With the death of Kublai Khan in the following year, further attempts against the island were abandoned. At the height of its power in the 14th century, the empire of Majapahit had almost the entire Archipelago under its sway. In 1478 the empire was overthrown by Moslem invaders, and Islam began to spread in the island. On the fall of the Majapahit empire the country once more split up into a number of kingdoms. In 1578 the ruler of one of these States assumed imperial power and founded the empire of Mataram which lasted till 1755 when it was divided into two kingdoms—Surakarta and Jokjakarta. The Dutch first arrived in Java in 1595, and thereafter, what with the growing influence of Islam and what with the increasing efforts of the Dutch to acquire possession of the island, Hinduism began to wane and was at last forced to quit Java and seek refuge in the small neighbouring island of Bali, where it survives to the present day as a mixture of Brahmanism and Buddhism, the former predominating. The Javan States of Surakarta and Jokjakarta still exist, but as dependencies under the Dutch Government.

Sumatra too in the long course of time fell a prey to foreign influences. In the 13th century a portion of the northern half of the island was invaded by Arabs, and Mahomedanism began to replace the ruling religion. Yet Sumatra seems to have continued as a Hindu-Buddhist State till at least the beginning of the 16th century, for when the Portuguese navigator Alphonso d'Albuquerque visited the Archipelago in 1510, he found the island ruled by a king named Paraméshwara.

The 'Benares' of Central Java is a remarkable group of ancient temples or Tjandis as they are called in Javanese. They are

numerous and are situated on the Dieng plateau in Central Java. Tjandi Kalashan, though ruined, is a magnificent building with beautiful sculptures. The largest and finest is Tjandi Bimā. It is a pyramidal tower with horizontal stages one above the other, and cornices with dormer-arches in which the heads of celestial choristers are framed. The best preserved in the group is Tjandi Ardjunā. It follows the type of Kalashan. The plan is square. The group consists of four temples, each having two storeys, with a roof imitating the body of the temple. The walls are ornamented with sculptured panels with pilasters between, and the doorway is crowned by a crocodile face. Bimā and Ardjunā groups are believed to have been built between the 7th and 8th centuries. There are many older temples in the same area. The finest of the earliest sculptures are the bas-reliefs of the Hindu Trinity in Tjandi Shrikandi. The date assigned to this group is 7th century.

Java boasts of many more ancient religious buildings of remarkable beauty. The most famous and imposing in the whole ruins is Bōrō Boeder or Bārā Budur ('Many Buddhas'), a gigantic stupa or relic mound. It is situated on a hillock rising 154 feet above the plain and commands a picturesque view of volcanic peaks towering in the distance. It was built in 750-860. It is in a rich style which, in its outward form and sculptural details, shows a mixture of Brahmanic and Buddhistic influences. The building presents a close resemblance to older stupas in the Punjab and contemporary structures in Kashmir. The hillsides are cut in a series of terraces which serve as procession paths for *pradakshina* or circumambulation, with four ramparts, one above the other, between the third terrace and the fourth. The lowermost terrace is 497 feet square. The entire structure is surmounted by a dome 52 feet in diameter, with 15 lesser bell-shaped cupolas artistically distributed around it. On the outer side of the wall of the second enclosure, 365 feet square, are 104 large niches. Each of these enshrines a Buddha seated on a lotus throne, the image and the seat being hewn out of a single block of stone 5 feet high. Along the inner sides of the pradakshina paths there are no fewer than 568 reliefs representing scenes from the life of Buddha which, it is stated, would cover, if placed end to end, a length of nearly three

miles! Some of the galleries are enriched with reliefs of Vishnu, Garuda (Vishnu's vehicle) and Shiva. The upper terraces display a series of dagōbas—dome-like sanctuaries surmounted by inverted pyramids and enshrining the relics of Buddhist saints—objects familiar to those in Bombay who have visited the chaitya caves at Kenheri in Thana District or those of Kārli, Bhājé or Bedsa in Poona District beyond Lonavla. In the dagōbas at Bārā Budur are placed seated figures of Buddha. The sculptural work at the lower terraces has not been executed as carefully as at the upper ones. But judging from the photographs, the massive structure is marked by a wonderful wealth of decoration and in several places is carved with a boldness and expression of power not often surpassed in religious edifices even in India.

About three miles north-east of Bārā Budur lies Tjandi Mendut, which belongs to the 9th century. It has an open porch covered with sculptures, and the outer walls of the body of the temple are elaborately adorned with figure-reliefs. Besides a large, handsome image of Buddha the temple contains figures of Buddha remarkable for the sublime serenity and graciousness reflected in their expression. Standing on either side of him everywhere is a Bōdhisatva with an equally serene appearance. These sculptures not only testify to the skill of the artists employed for the work, but also show the depth of devotion and religious ardour with which they were inspired in its execution. Java contains several other monuments associated with the Mahāyāna school of Buddhism. Soon after the completion of Bārā Budur Java saw a vigorous revival of Shaivism, attended by deep religious fervour which lasted nearly three centuries. About 900 A. D. were built three large Brahmanical temples at Prambanan, which form the group of Tjandi Lōrō Djonggrang. The central one, which is the most impressive in the group, is dedicated to Shiva and is adorned with bas-reliefs illustrating scenes from the Ramayana. It stands between two other shrines, of Brahma and Vishnu respectively, with a temple of Nandi, Shiva's riding bull, in front.

After the first decade of the 10th century Central Java fell into neglect for a long period, and the centre of culture was transferred to the eastern part of the island under the rulers of Kediri, Singasari (1280–1292) and Majapahit. The 13th century saw a number of

exquisite sculptures executed in Singasari, including statuettes of Ganésha, Durga and other deities. In a wood near Malang in the vicinity of the unfinished Shaivite temple of Singasari was found in 1819 an extremely beautiful image of Prajnāpāramita, the counterpart in Buddhist iconography of the Hindu goddess of learning and wisdom, Saraswati. This statuette, now in the museum at Leyden (Holland), is generally accepted as a masterpiece of Indo-Javanese sculpture. In the course of an article in the 1931 November-December number of *Trivéṇi*, a leading journal of Madras, Mr. T. N. Ramachandran gives the following description of this image, partly based on Havell's description of it:—

> 'Seated in a state of complete abstraction on a lotus flower, the symbol of purity and divine birth, in the fixed pose of a *yōgini*, the goddess performs with her hands the divine *mudra* or sign of spiritual instruction, while her charming face has "that ineffable expression of heavenly grace which Giovanni Bellini, above all other Italian masters, gave to his Madonnas." The head-dress, ornaments and dress with which the goddess is provided are exquisitely and elaborately worked. The scripture is placed on a lotus flower to her left, the stalk of which is twined round her left arm.'

The writer adds that the image is ascribed to the reign of Ken Arok (Rājasa Sang Amurvabhūmi), *i.e.*, 1220-1227.

Many other parts of Dutch East Indies are of great interest on account of the evidences of ancient Hindu colonization still to be found there. In Sumatra are found numerous traces of Hindu influence. Ruins of Hindu temples exist at Butar in Deli, at Jambi, in the interior of Palembang and in many other localities. There are also stone inscriptions in Sanskrit, one of which calls Sumatra 'First Java'. The most important of Buddhist monuments which survive is the stupa of Muara Takus on the upper reaches of the Kampar river.

Bali or Little Java likewise received a stream of colonists from India direct, as is shown by inscriptions on brass tablets found in the island. The Hindu colony was strengthened later by Hindu-Javanese settlers. Even at the present day the Hindu gods Brahma, Vishnu and Krishna are known to the Balinese. Their modern temples or *puras*, which are small wooden structures built on stone foundations, exhibit many features of Hindu styles of architecture. The better class of temples are dedicated to Shiva, and the form of the familiar god Ganésha is sometimes seen in them. Many of

the Balinese social and religious customs are of Hindu origin. Suttee was practised for centuries until the Dutch Government put a stop to it. Dead bodies are cremated as among the Hindus.

In the 1931 May number of *Vēdānta Kēsari*, Dr. R. C. Majumdar gives an interesting account of the first phase of Hindu civilization in Borneo, the largest island in the archipelago. The earliest and most illuminating records of Hindu colonization of it are furnished by four inscriptions engraved on four sacrificial pillars or *yupas* as they are called. They were discovered in the Koetei district in Middle East Borneo at a place named Muara Kaman on the bank of the Mahakam river. These inscriptions include references to Brahman settlers and to a king named Kundariga and his son Ashvavarman and grandsons. The eldest of these last named Mulavarman, says one of the inscriptions, performed in a grand style a sacrifice called Vahusuvarnakam. One of the pillars, says another, was erected by the Brahmans to commemorate a gift of 20,000 cows made by the king Mulavarman to Dwijas (the 'twice-born'). In western Borneo too traces of early Hindu colonization have been discovered. Ruins of temples and images have been found at various places on the banks of the Kapuas river. Majumdar considers that the images found here and elsewhere in the island afford unmistakable proof that the earliest Hindu settlers of Borneo also came direct from India. The fact that the title of Varman adopted by Hindu rulers in Borneo is one which was held by Pallava kings, for instance, Mahéndravarman, Narasimhavarman, Paraméshwaravarman and Nandivarman of the 7th and 8th centuries, suggests the probability that the first Hindu settlers in the island were from Southern India. Evidences have been found that the immigrants also penetrated to the interior. In the Kombeng Caves lying on a hill situated north of Muara Kaman have been found numerous sandstone images, some of which have been identified as those of Vishnu, Skanda (Shanmukha or Kārtikéya), Nandi and Ganésha. Three images of Shiva along with a beautiful bronze image of Buddha in standing attitude found in the island have been removed to the museum at Batavia. From another source we learn that even in the inmost recesses of the mountains, and in one case in a region 400 miles from the coast, have been found the ruins of temples of excellent workmanship which show all the

features of Hindu places of worship. Among other interesting finds is a gold pendant representing a four-armed Vishnu with lateral Garudas. The general opinion is that all these remains are assignable to the 7th or 8th century.

Besides the temples, inscriptions etc. there are numerous localities in Dutch East Indies whose geographical names are reminiscent of ancient Hindu colonization, *e.g.*, Purwakarta, the administrative centre of the Residency of Krawang; Wanasaba, a place of pilgrimage near Dieng plateau dedicated to Shiva; Sukabumi, one of the Preanger Regencies and a pleasant health-resort about 2,000 feet above the sea, and the volcanic peaks of Seméru, Guntur, Ardjunā and Rāwun—all in Java; the islands of Sangkapura and Madurā north of Java; Singarādja, the capital of Bali Island; a district, town, river and volcano, all bearing the name of Indrapura, the river Indragiri and the district of Lingga; all in Sumatra. In the last-named island, the northernmost division has for its administrative centre a city called Kōta Rādja; the Residency of the East Coast includes an island and a port, both named Bengkālis, the Residency of Tapanuli a dependency called Angkōla, and the Residency of Padang includes the port of Priaman and the dependency of Rau.

A part of the material for this Note is drawn from the *Encyclopaedia Britannica.*

(50) Elevation of the World's Hottest Spring —the one at Guanaxuato, Mexico } 6,500 ft.

Note.—According to Surgeon-General Balfour, this spring was discovered by the traveller Humbold who describes it as the hottest spring in the world with a temperature of 207° F. (97° C.)

The boiling point of pure water, which at sea level is 100° C. (212° F.), drops about 1°C. for every 1,000 ft. rise above sea level owing to the diminishing air pressure. Thus on the top of Mont Blanc (15,782 ft.), the highest peak of the Alps, water boils at about 84·5°C. (184°F.). At an elevation of 6,500 ft. the boiling point will be about 93·3°C. (200°F.). The fact that the temperature of the Mexican spring exceeds the usual boiling point at its elevation shows that its water contains salts in solution. If the water were free from them, its temperature would not be higher than the usual boiling point at that level. Even at sea level the boiling point of sea-water or any other water containing salts in solution is higher than that of pure water and varies with the amount of dissolved matter present in it.

(51) Greatest Height which Haze has been found to reach } 7,000 ft. (*Negretti & Zambra*)

Note.—This height was once reached at the village of Farnborough in Hampshire, England.

(52) Height from which a Hail-storm over the earth is seen in the fulness of its weird grandeur } 7,000–8,000 ft.

Note.—Hail consists of two types: solid or true hail, and soft hail, a form of snow. The former results from the freezing of rain-drops. Vertical air currents result in the formation of a thick cloud, generally cumulo-nimbus or thunder-cloud, where tiny drops of rain are formed and borne upward, freeze in the cooling air and form themselves into hailstones. These stones, as they come down, are enveloped by a further layer of water-vapour, which in turn may freeze by their rising again in another part of the storm. In such cases two or more stones unite and attain large dimensions. Hailstones vary from ¼ inch to 4 inches in diameter, the largest weighing a pound or even more. A hail-storm is destructive to crops, especially in tropical climates. It is shown by statistics collected over a large number of years that the regions most liable to hail-storms are those which are devoid or denuded of forests. The duration of a storm is usually a few minutes only. Hail sometimes accompanies thunder-storms in summer. Soft hail consists of little spherules of compact ice particles which break with a splash when they strike hard ground. It also accompanies storms in spring or winter.

The airman, Captain Norman Macmillan, describes a hail-storm as witnessed from an aeroplane as follows:—

'There is no grander sight in the air than that at seven to eight thousand feet when hail is forming above the earth. Big clouds lour black around one. A steep wall rises upward from a sea of tinted grey to a ceiling of translucent pearl. Suddenly against the almost black wall there is a slash of streaming white. It grows from nothing out of the pearl above and falls slanting across one's closing vision. For 1,500 ft. it drops its curtain over the gloomy stage. No sun is visible in all the solemn air. The atmosphere is cathedral. Since with the noise of the engine no further sound is audible, the eeys must take upon themselves the duty of the other senses. And in one's ears one seems to hear, as though it were just all around, hissing upon the vaulting roof and wall of the cathedral of the clouds, the beating of the hail-storm. It is a sight which audibility would reft of more than half its splendour.'

(53) Elevation of the World's Largest Active Crater—Aniakchak in Alaska, North America } Over 8,000 ft.

Note.—In the *Illustrated Weekly of India* of 21st December 1930 appeared a short report of the discoveries made in the region of this volcano by an expedition led by the Rev. Father Bernard F. Hubbard, head of the Department of Geology at the Jesuit University of Santa Clara in California and known to scientists as the 'Glacier Priest'. The crater has been found to be 21 miles in circumference and is stated to be the largest active crater in the world. Dozens of active fumaroles or smoke-holes have been found in it. Among other objects of interest found was an obsidian or natural glass cliff (formed by vitreous lava rapidly cooling) 600 ft. high, 'broken into columnar structure, its flat surfaces iridescent like a raven's wing.' For further particulars, *vide* Chapter IV.

There is another active crater named Veniamenoff in this region, nearly as large as Aniakchak. There are also enormous volcanoes in the island of Unimak, which lies so close to the mainland as to form practically a part of the peninsula.

The *Encycl. Brit.* (*1929*.) mentions a crater named Aso-san (5,545 ft.) situated in the island of Kiushiu in Japan. It is 'a huge oval depression estimated by some observers to have an area of at least *100 sq. miles*'. The same work in another place includes this volcano in the list of those still active in Japan and remarks that its crater, measuring *10 by 15 miles*, is the largest in the world. But along with Aso-san is given in the list another volcano 'almost extinct'. It is possible that Aso-san has been quiescent for a very long time and is no longer classed among active volcanoes.

A writer in the *Illustrated Weekly of India* of 13th December 1931 describes a large crater, an extinct one, situated in Tanganyika Territory, Africa, about half way between the port of Mombasa and the southern banks of Lake Victoria. 'The floor of this cyclopean amphitheatre', he says, 'is like a gigantic bowling-alley, a smooth, open plain of short grass and clover nearly 6,000 ft. above sea and holds, towards its far side, a *magad* or salt lake, 4 miles by 3, bordered by papyrus or acacia forest.' The crater has steep walls descending nearly 2,000 ft.

(54) Elevation of the Grand Canyon of the Colorado River, U. S. A. } 5,000–9,000 ft.

Note

Canyons are winding series of deep, abrupt gorges at the bottom of many of which run turbulent rapids inaccessible to man or beast. They are found in Mexico and the south-west of the United States. Their rocky walls are sometimes perpendicular and are worn and intricately sculptured into impressive forms. The effect is heightened by diversity of colour, for the various groups of strata of

which the walls are composed display an artistic arrangement of pale grey, light green and pink hues, and in the depths slate-grey and chocolate-brown tints. 'Its distances are often suffused', says the *Encycl. Brit.* (*1929*), 'with a transparent blue-purple haze that contrasts with the deep-green of the pine trees on its rim and the intense blue of the sky.' The canyons are one of the most striking of geological phenomena. The Grand Canyon, which has complex ramifications, cuts across a plateau and is 280 miles long and 5 to 18 miles broad. Its walls rise sheer from the water's edge to the stupendous height of 2,000 to 6,000 ft. Its grandest part, 105 miles in length, lies within the Grand Canyon National Park. The American Government have prepared detailed maps of this canyon.

The earth's land surface is ceaselessly subjected to the action of numerous forces. Various agencies wear away the rocks, detach from them materials termed *detritus* and carry them to distant parts. The entire process is called *erosion* when the attrition is vertical, or *denudation* when it is superficial. Water, ice chiefly in the form of glaciers, frost and wind are the principal wearing and disintegrating agencies which often work together. The most powerful agents of denudation are rivers, and it is due in some measure to the friction of the water but to a great extent to attrition of the debris, during its passage, against the hard bed of the swift-flowing river. Rivers coming to parched regions from outside sources may excavate narrow and deep chasms with steep sides. In the Colorado Canyons the elements also must have played their part in loosening the material of the rocks and in altering their form and colour, or in rounding off their edges or even in breaking up the land and carving the scarped sides. Such a process is known as *weathering*, a term which has even a wider import than indicated here. But the most remarkable feature in the operation of natural agencies in the present case is the power of the river to erode vertically.

It is estimated that the forces of Nature have been at work for upwards of a million years in the formation of the Grand Canyon.

Another notable instance of the erosive power of a river occurs in Utah, U. S. A., where there is a bridge of rock called the Edwin Natural Bridge. It is 90 feet high and 200 feet long. It has evidently been scooped and scoured out by the force of the rushing

waters below. This is another wonderful example of the proverb 'Running water wears away stones.'

The American Government have a titanic irrigation scheme in hand. "It is the Hoover Dam, which will rise 527 feet high from the floor of the Boulder Canyon in California. The Colorado river at flood-time has sometimes assumed gigantic proportions. This dam is intended to impound the flood waters of its basin which have so long been running to waste. The waters which it will store will be released when desired and will come rolling down between the parched hills of Arizona on one side and of California on the other. It will bring water to the most arid and tropical part of the country and convert barren desert tracts into farming areas. The dam is expected to take five years to be completed and will stand forth as one of the greatest of human achievements in harnessing the forces of Nature.

(55) World's Altitude (Height) Record for Solo Flights by Gliders } 9,780 ft.

Note.—This height was reached in a flight at Gersfeld in Germany by the famous Vienna gliding expert, Robert Kronfeld, in 1929. A greater height was attained in June 1931 by a Swiss pilot, but his flight was made from the top of the Alpine peak, Jungfrau Joch (11,340 ft.), whence the glider was launched down the mountain slope. He made one or two circuits at this altitude, then flew down into a valley and finally landed near the village of Lauter Brunnen after a flight of 1 hour 45 minutes.

(56) Strato-Cumulus or better Cumulo-Stratus Clouds } 3,200–10,000 ft.

Note.—These are large, dull grey, lumpy masses of cloud with the Cumulus at the top overhanging a flattish stratum or base. They are the lowest form of sheet cloud and often cover the whole sky, particularly in winter. They merge into the Alto-cumulus (Item 89 below).

(57) World's Altitude Record for Heavy Aircraft carrying a large number of men } 10,000 ft.

Note.—This record was established in August 1931 by *Do-X II* or *I-Redi*, sister ship of the famous German Dornier treble-decker flying boat *Do-X*, during its flight from Allenstein to Spezia, when it flew over the Alps at the above mentioned height. It had a passenger load consisting of a crew of 12 men and a Commission of Italian officers. It alighted on the Grand Canal in Venice and since the machine had been ordered by the Italian Government, it was formally made over to them at the termination of the flight.

The 55-ton air leviathan *Do-X* created a sensation in October 1929 when it made its trial flight with 169 persons on board over Lake Constance. The boat rose from the water in half a minute and flew three-quarters of an hour, attaining a speed of 135 miles an hour in the flight. It made a successful trans-Atlantic trial flight in 1931.

These flying boats, it is said, embody an entirely new principle—that of adapting a ship to the air instead of adapting an aeroplane to the sea.

There is only one instance so far where a passenger load exceeding 169 persons has been carried by any type of aircraft. The *Akron*, America's armed dirigible and the largest airship in the world, which was completed in 1931, carried 207 passengers on 3rd November 1931 when it left the aerodrome at Lakehurst, New Jersey, on a 500-mile trial voyage.

(58) Greatest Height at which the discharge of a Gun has been heard — 10,000 ft.

(59) World's most elevated Aerial Beacon—the one just west of Cheyenne, Wyoming, U. S. A., installed for the benefit of night-fliers — do.

(60) Elevation of the World's Deepest Extinct Crater—Haleakala ('House of the Sun') in the island of Maui, Hawaii Islands — 10,032 ft.

Note.—This crater is 2,720 ft. deep. Its circumference at the bottom is 20 miles and at the rim 19 miles. The article in the *Illustrated Weekly of India* referred to in the last paragraph of the Note under Item 53 mentions an extinct volcano named Elanairobi situated in the highlands some distance from Lake Natron in Tanganyika Territory, Africa, the crater of which, 5 miles wide, is filled with virgin forest and is 3,250 ft. deep in its gullet. Until fuller details of the exploration of this crater are available, we must hesitate to assign to it the first rank in the world in point of depth.

(61) World's Fifth Highest Group of Thermal or Hot Springs—the springs at the celebrated shrine of Badrinath, Garhwal, Himalayas — 10,294 ft.

Note.—Badrinath stands on the bank of the Alaknanda, a head-stream of the Ganges and here known as Vishnuganga. There are two springs here named Taptakund and Suryakund. The latter issues from a fissure in the bank of the Vishnuganga. Taptakund water is said to be sometimes so hot as to be scarcely bearable until it is cooled by the mixture of cold water from another spring. On a 26th of May at about 11 a.m. its temperature was found to be 49° C. (120° F.). The water sends forth a dense vapour having a sulphurous odour.

(62) World's Fourth Highest Group of Thermal Springs—those at the Himalayan shrine of Gangōtri (Tehri State) on the Bhāgirathi — 10,319 ft.

Note.—The Ganges has three head-streams, *viz.*, the Bhāgirathi, the Mandākini and the Alaknanda. The chief of these are the first and the last. Opinions differ as to which of these two is the source of the Ganges. Hindu religious view favours the Bhāgirathi, which issues from Gômukha, an ice cave at the foot of the Himalayan snow-bed near Gangôtri. Geographers incline to the view that the source is the Alaknanda, as this stream has a much longer course and a considerably larger body of water throughout the year. At the junction of these two streams is the sacred place of Dévaprayāg, the head-quarters of the Badrinath Pandas, and it is from this point that the river is known as the Ganges.

(63) Perhaps the most elevated Railway Tunnel in the world more than 2 miles in length—the one below the Uspallata or Cumbre Pass in the Andes Mountains — 10,469 ft.

Note

This tunnel is on the Trans-Andine Railway, the first trans-continental railway in South America, which connects the Pacific port of Valparaiso, Chile, with the Atlantic port of Buenos Aires, Argentina. The tunnel is a little over 2 miles long and took nearly four years to complete. It was opened for traffic in 1910.

A few other noteworthy mountain tunnels may be mentioned. The Moffat Tunnel in U. S. A., which crosses the Continental Divide, about 50 miles west of Denver, Colorado, is 6·1 miles in length and lies at an elevation of 9,200 ft. It is the longest railway tunnel in America. It was commenced in 1923 and completed five years later. The Cascade Tunnel of the Great Northern Railway in the State of Washington is 7·79 miles long. It was begun in 1925 and finished four years later. The unscalable barriers of the Alps have been tunnelled at some places. The first to be conquered was Mont Cenis whose tunnel, driven for the greater part through solid granite, was started in 1857 and took fourteen years to complete. It is 7·98 miles long, about 26 ft. broad and 25 ft. high, and connects France with Italy. The Saint Gothard Tunnel in Switzerland, commenced in 1872 and finished in 1881, is 9·3 miles long, 18 ft. wide and 25 ft. high.

It was also burrowed out of granite rock. Its chief interest reposes in the fact that it winds around inside of the mountain, spiralling towards the summit. The Loetschberg Tunnel, also in the Swiss Alps, is 9·04 miles in length. It was commenced in 1906 and opened for traffic five years later. The great Simplon Tunnel, started in 1898 and finished in 1905, is 12·3 miles long and connects Switzerland with Italy. It is the longest railway tunnel in the world. Describing the difficulties met within its excavation, a writer says:—'Here all the giant forces of Nature seemed to unite to defeat their would-be conqueror. She would not face him with her solid rock, but tossed gneiss and treacherous mica-schist, limestone and disintegrated stone in his path. She spouted 10,000 gallons a minute of icy water into his tunnel on the Swiss side and a gusher of hot water into it on the French side.' The cold spring on one side brought down the temperature to 55·4°F. (13°C.), while the hot spring on the other, which spouted 1,600 to 4,300 gallons a minute, raised the temperature to 113° F. (45°C.).

There is another remarkable Alpine tunnel whose average elevation we have not been able to ascertain with any precision. It lies in the Bernese Alps on the electric railway road, the highest railway in Europe, from Scheideck to Jungfrau Joch (11,340 ft.). This railway was completed in 1912. The *Encycl. Br.* (*1929*) in one place says that this line 'passes by a tunnel 4½ miles long through the Eiger, Mönch and Jungfrau Joch', and in another:—'The electric railway from Eiger glacier to near the summit of the Jungfrau includes a tunnel 1·5 miles long, 11 ft. 10 in. wide and 12 ft. 6 in. high, with a midway station having arches through the side from which a large part of Northern Switzerland can be seen. From the Jungfrau terminus, at an elevation of 13,428 ft., the summit, 242 ft. high, may be reached by an elevator.' Judging from these meagre and apparently conflicting descriptions, the tunnel is perhaps not a continuous one but divided by gaps. Fuller details will show whether any section of it exceeds 2 miles in length and lies at a higher elevation than the trans-Andine tunnel below the Cumbre Pass.

The trans-Andine tunnel is a replica of the Alpine tunnels, and the pathway had to be arduously bored similarly by powerful drills driven by compressed air. The engineers and workmen had to work

amidst severe hardships. At first they suffered from mountain sickness, while during the long months of winter they were exposed to intense cold. Furious blizzards would suddenly spring up and bury the shelters housing the workers several feet deep in snow.

(64)	Record Height at which the Barking of a Dog has been heard	2 miles
(65)	Greatest Height (above ground) at which Bacteria or disease-carrying organisms have been found active	do.

Note

Professor Dillon Weston of the Cambridge University of Agriculture, who in 1929 was in control of operations by aeroplane to discover how epidemics are broadcast through a thin air current, has collected valuable information on the subject. Careful experiments showed that human diseases could be transmitted over long distances through the upper air. Numerous bacteria are active even two miles above the earth's surface. Clouds form a particularly fine vehicle, being more heavily charged with bacteria than the air immediately below.

A bacterium is a vegetable micro-organism and one of the minutest of living organisms; and yet a scientist estimates it, roughly, to be a million times larger than the largest organic molecules or a billion times larger than 'a few score electrons' (the negative particles of an atom)! To convey at the same time an idea of its minuteness, he adds that its size is a trillionth that of a butterfly. But infinitely small as the bacterium is, there is an organism considerably smaller than this microbe and smaller even than the filtrable viruses of smallpox, rabies and yellow fever which are, as a rule, minuter than ordinary bacteria. It was discovered in the second decade of the present century. This remarkable organism is a parasite which infests bacteria and is said to be a thousand times as small. It is named *bacteriophage*, a term which means 'eater of bacteria'. This discovery reminds us of Lowell's familiar lines:—

'Great fleas have little fleas
Upon their backs to bite 'em;
And little fleas have lesser fleas,
And so ad infinitum.'

We shall not be surprised therefore if a still smaller living organism is discovered hereafter and it is found to be the parasite of the bacteriophage!

The *modus operandi* of the bacteriophage is interesting. Having settled on a bacterium, it penetrates into its body, then makes more and more room for itself as it sucks up its juices, and finally lays eggs there. At last the lifeless shell of the victim bursts, and the new-born bacteriophage are ready to pursue similar operations on other bacteria. The bacteriophage by its rapid multiplication evidently serves to keep down the number of bacteria, for the bacterium is a very prolific organism and a single organism doubles itself in about twenty minutes, so that it becomes a grandfather in less than an hour! The bacterium is probably the most tenacious of all living organisms. Some species can live without air for an indefinite period, while others resist cold of extreme intensity. Dr. J. MacFadyan, an American Professor, was unable to kill certain types of bacteria even by keeping them in a bottle of liquid air for twenty-four hours! Liquid air represents a temperature of $-195{\cdot}8^0$C. ($-320{\cdot}44^0$ F.). Dr. C. A. Magoon of the United States Department of Agriculture told a meeting of the American Chemical Society that some of the worst forms of bacteria were found to remain alive for ten hours even in liquid hydrogen! Now hydrogen liquefies at -422^0F. (-252^0C.), a temperature representing over 450 degrees of frost on the ordinary English scale, a temperature so low as to turn solid all the gases of the atmosphere except hydrogen and helium! Liquid hydrogen is so cold that like liquid air, when dropped on a cake of ice, it boils furiously. Even at much lower temperatures hard metals become as brittle as glass, and a metal bar as fragile as a twig.

The longevity of some bacteria is so amazing as to be almost incredible. Certain types have been recently found in a coal-seam in Germany. Coal, as explained in our first chapter, is a mass of compressed and mineralized vegetable matter. It belongs to what is called the Upper Carboniferous system which in Europe began to form in the later period of the Palaeozoic Age. The bacteria discovered in the coal must have lodged themselves in it since the time it was laid down, and been effectually entombed there for so many hundred million years! That they should have survived through

all these ages the stupendous pressure of the overlying load of rock and soil and lived all along without free oxygen, is simply marvellous. These particular microbes are luminous and emit a soft glow like fire-flies.

The bacterium may thus be regarded, in many respects, as a preternatural phenomenon among earthly organisms. It is, however, killed by ultra-violet rays.

Luminous bacteria are not so rare as might generally be supposed. Putrescent fish and flesh and other decomposing organic matter often emit a gentle glow owing to the presence in them of luminescent microbes. As these organisms are very minute—something like 1/25000th of an inch in diameter—it is impossible to see them individually in spite of their light. But when present in vast colonies they are easily visible. Like luminous fungi these types of bacteria glow both night and day, but to be able to emit light they need air or oxygen. Experiments have shown that they cease to shine when placed within an air-pump and the air is exhausted, but become luminescent again with the readmission of air. The light of these bacteria is absolutely cold and is due to the same chemical agencies as in fire-flies and luminous fishes and fungi.

Dr. F. d'Herelle, a French physician working in Yale University and one of the discoverers of the bacteriophage, visited India some years ago at the invitation of the Government to assist in the extermination of cholera in this country. He centred his activities around the holy city of Puri (Jagannath), as cholera was then raging in that town and the district. The wells had become contaminated and the epidemic spread rapidly. The doctor and his assistants prepared solutions of cholera-bacteriophage and dumped quantities of the liquid into the wells in the whole district with the result that the death rate and number of attacks fell off in a short time.

The Ganges river is looked upon with great veneration by the Hindus. It is well known that its water is defiled by every sort of filth cast into it by man and beast and yet pilgrims drink mouthfuls of it, take home vessels filled with it, distribute it and sip it at religious functions. Among Hindus it is even customary to pour a spoonful of it into the mouth of the dying. It is an age-long and almost universal belief with Hindus that in spite of its pollution the gods protect the partakers of this holy water from evil effects.

This belief has proved to be sound as a result of research in bacteriology.

It was found many years ago that Ganges water contained the bacteria of some of the deadliest scourges of mankind and yet its internal use produced no harm. For a long time the mystery remained unsolved. At last a new generation of scientists made a fresh attack on the problem. They arrived at the theory that the water nourished other kinds of organisms so minute as to defy detection with the most powerful microscopes and that these tiny organisms were annihilating the bacteria. The theory was put to the test. A quantity of Ganges water was filtered in such a way as to leave, according to all known laws of science, no organism alive in it. The filtered water was treated in the required manner to obtain a culture of bacteriophage, but without perceptible result. A few drops of it were then poured into a test-tube containing a slightly milky culture of the most virulent bacteria—the germs of such diseases as cholera, dysentery and enteric. The milkiness in the tube disappeared, and its contents were carefully examined with a microscope. All the bacteria were found to be dead. It was thus definitely proved that Ganges water contained, side by side with malignant bacteria, filter-passing organisms which attacked with deadly effect bacteria of the types bottled in the test-tube. These experiments have been pursued further, and it is claimed that bacteriophage inimical in their natural element to bacteria of a single disease can be trained to attack two kinds of bacteria and later three or four.

The School of Tropical Medicine at Calcutta, availing itself of these valuable results, produced a culture a few drops of which, administered through the mouth to a dysentery patient, have, it is stated, effected in a few hours a cure which normally takes days or weeks. But this new remedy has not always proved infallible and not all medical men accept it as an absolute cure.

(66)	Greatest Height at which a Locomotive Whistle has been heard	Over 2 miles
(67)	World's Third Highest Group of Thermal Springs—the Baths at Toro near Elqui in Province Coquimbo, Chile, South America	10,690 ft.

14

(68) World's Second Highest Group of Thermal Springs—those at the famous shrine of Jumnôtri (Tehri State), Himalayas } 10,800 ft.

Note.—Jumnôtri is situated 4 miles below the glacier to which the river Jumna owes its source. Close by the Jumna temple lie a number of very hot springs from which water issues at a temperature of 90·4° C. (194·7° F.). The pilgrims cook rice in these springs.

Many hot springs occur in the Ladakh Province of Kashmir, and it is possible that some of them lie at a higher elevation than the Jumnôtri group, but we have no information on this point. The best-known of the Ladakh springs are those at Nubra and Puga, and their temperature is 75°C. (167° F.). The water is clear, and there are beds of soda below the springs. The Puga springs lie in the bed of a stream where they bubble out at temperatures ranging from 26·7° to 60° C. (80° to 140° F.). The hottest contain sodium chloride and sulphuretted hydrogen in solution, and those of lower temperatures sodium chloride and sodium borate.

(69) Most elevated Observatory in India—the one at Leh, Ladakh Province, Kashmir } 11,503 ft.

Note

This is a meteorological observatory. Two other weather stations above 10,000-ft. level maintained by the Indian Meteorological Department are at Dras (10,059 ft.), Kashmir, and at Kailang (10,087 ft.), Kangra District, Punjab.

A fully equipped meteorological observatory will have barometers, and at least one barograph to record the changing atmospheric pressure on a moving drum; thermometers for maximum and minimum readings of the air temperature, and thermographs for recording them; a psychrometer which, by reference to tables, gives relative humidity or moisture in the air, dew point and vapour pressure; a hygrometer and hygrograph, for determining humidity; an anemometer to give velocity of wind; an anemoscope or wind vane, for direction of wind; a nephoscope for making observations of cloud movements, their direction and velocity at a given time; and a rain-gauge for measuring the quantity of rain which falls at a given place during 24 hours.

There are about 250 observatories in India maintained by the Meteorological Department which take daily weather records. At the main or first class observatories, besides the usual weather-

recording instruments there are seismographs, delicate instruments which can record earthquakes occurring as far away as Peru. The chief centre for this work is the Colaba Observatory at Bombay. The principal observatory for work in terrestrial magnetism is the one at Alibag in the Kolaba District of Bombay, a place which lies on the magnetic equator. There is also an astronomical side to the Department's work. The fundamental time-keeper with which clocks and watches have somehow or other to be compared is the transit overhead of the sun or of the stars. The Colaba and Calcutta observatories make these fundamental comparisons and operate the time-signals at the ports for the benefit of shipping. The Railway and Telegraph clocks are set by the Calcutta time-signal, and they form the standard by which the general public set their own clocks and watches. The chief astronomical observatory is the one at the Kodaikanal hill-station (District Madura, Southern India) which has the specialized function of studying solar physics. Here is made a systematic study of the sun and solar phenomena by means of the spectroscope, spectro-heliograph and other instruments. The work at Kodaikanal and at the Magnetic Observatory at Alibag is carried out in accordance with an internationally agreed programme.

The means adopted by the Department to fulfil its weather-forecasting duties shows the well-organized manner in which they are conducted. A corps of observers at different stations read standard instruments in standard exposures at uniform intervals and keep their records according to a uniform plan. There are more than 3,000 rain-gauge observers in India who take observations every morning at 8 o'clock according to a uniform plan and about 300 observers who take fuller simultaneous observations at about 200 separate places and telegraph them to one or more forecasting centres, where, for rapid assimilation, their telegrams are decoded and weather charts drawn. The organization is so extensive that telegrams from as far away as the Persian Gulf and Aden on the west and Burma on the east, based upon observations taken every morning, are received, decoded and plotted out at Poona, the head-quarters of the Department, before 11 a.m. The preparation of weather-maps at selected centres is the basis of every modern weather service. These maps are essential for checking the work of the various observers, and they supply the data on which to base

the forecasts. The daily weather-maps are occasionally supplemented by special observations, and the meteorologist is thus enabled to forecast the major events of weather such as cyclones and widespread heavy rainfall. Some of the observatories take observations for climatological purposes, but do not telegraph them.

The duties of the Meteorological Department are multitudinous. They include: (1) The issue of timely warnings to ports and coastal districts of the approach of violent storms. Since the introduction of wireless telegraphy this duty has been extended to include the issue of warnings to ships in Indian seas. (2) The maintenance of systematic records of meteorological data and the publication of climatological statistics. These were originally undertaken to furnish data for the investigation of the relation between weather and disease. (3) The issue to the public of up-to-date weather reports and of rainfall forecasts. These duties were originally recommended by a Committee of Enquiry into the causes of famine in India. (4) Meteorological researches of a general character, but particularly regarding tropical storms and the forecasting of monsoon and winter rainfall. (5) The issue of seasonal rainfall forecasts. (6) The issue of warnings of heavy rainfall by special telegrams to District officers on the Departmental warning lists (*e.g.*, canal and railway engineers), and by means of the ordinary daily weather telegram to the general public. (7) The supply of meteorological, astronomical and geophysical information in response to enquiries from officials, commercial firms or private individuals. (8) Technical supervision of rainfall registration carried out under the control of Provincial Government authorities. (9) The study of temperature, humidity and pressure conditions in the upper air by sending up small balloons carrying recording instruments, and the study of upper winds by releasing and observing pilot balloons. (10) Observations and researches from time to time in terrestrial magnetism and atmospheric electricity. (11) The maintenance of seismological instruments at various centres for recording earthquakes occurring in different parts of the world.

To meet the needs of aviation which, of course, necessitate close and constant touch on the part of the meteorologist with such weather phenomena as fog, clouds, thick dust-haze, dust-storms and thunderstorms, the Department has regional forecasting centres at two points

along the main air-route, *viz.*, Karachi and Calcutta, where weather charts are prepared twice a day. It is responsible for the supply of weather reports and forecasts to aviators on routes also outside Northern India. Many of the weather phenomena are local and short-lived and are liable to rapid changes, and hence the need for observations more than once in a day.

The head-quarters office at Poona serves as the main forecasting centre for the Indian area and publishes the Daily, Weekly and Monthly Weather Reports and an annual volume entitled the *Indian Weather Review.* It undertakes the issue of heavy rainfall warnings for the whole country excepting north-east India, and the issue of warnings of impending storms in the Arabian Sea. It is responsible for practically all climatological work in India including checking and computation of data received from most of the meteorological observatories and the preparation of normals of rainfall, temperature, humidity etc. for all observatories. It collects and analyzes weather logs from ships in the Arabian Sea. It is responsible for the design, specification, test and supply of special meteorological instruments. Since its transfer from Simla to Poona, the office has been equipped as an upper air observatory and has also been designed to afford facilities for research in theoretical and practical meteorology.

The Alipore Observatory at Calcutta serves as a regional forecast centre for the air-route between Allahabad and South Burma, and is responsible for the publication of the Calcutta Daily Weather Report for north-east India, for storm-warning in the Bay of Bengal and heavy rainfall warning in north-east India. It has complete charge of all second and lesser class observatories from Assam to Orissa, while its other duties include the supply of time-signals to the Port of Calcutta and by wireless to shipping in the Bay of Bengal. It is also a first class weather observatory, pilot balloon observatory and seismological station.

For upper air work in India, the head-quarters is the Agra Observatory. It is responsible for the upkeep of all the pilot balloon stations in India and neighbouring countries and for supplying them with the necessary equipment for carrying out daily pilot balloon observations and supervising their work. These duties have necessitated the provision of a factory for the manufacture of

hydrogen gas and its compression into tubes, as well as the maintenance of a workshop for the repair of instruments and hydrogen tubes and the manufacture of upper air instruments. All data from pilot balloon observations are collected, checked and statistically summarized at Agra. This observatory is the principal centre of upper air research work in India.

The Colaba and Alibag Observatories specialize in the study of geophysics, particularly seismology and terrestrial magnetism, besides carrying out the duties of a first class weather observatory. They take star and sun observations for the determination of time and are responsible for the time—ball service at Bombay Harbour and the rating of chronometers belonging to the Royal Indian Marine and Royal Navy.

The Kodaikanal Observatory is the biggest in India and is known the world over. It stands on a peak of the Palni Hills at an elevation of about 7,700 ft. It is one of the comparatively few solar physics observatories in the world. Some of the important research work done here is referred to in our chapter on the Sun. But while the observatory specializes in this branch of astronomical study, it also undertakes the duties of a first class meteorological observatory and a seismological station. The only other astronomical observatory in India is the Nizamiah Observatory of Hyderabad (Deccan), which is exclusively occupied with problems of solar physics.

It is needless to point out that for all these duties which are of a complex and highly technical character a well-trained staff of scientists is necessary. Indianization of the services has perhaps in this Department more than in any other gone on apace. Almost all the first class meteorological observatories in the country and the Magnetic Observatory at Alibag are now under the direction of able and industrious Indian physicists, many of whom have distinguished themselves by their research work in seismology and other branches of geophysics, and in thunder-storms and other atmospheric phenomena.

A new branch of activity is being introduced at Poona to give effect to a scheme of research in Agricultural Meteorology, which will extend provisionally for a period of three years. The work will begin with a critical enquiry of the available data on the area and yield of crops for the different Provinces and Districts, which

will be subsequently correlated with accumulated meteorological data. There will also be an experimental or biological side to this work of investigation. The new branch will decide what meteorological and physical data should be collected regularly at the various experimental farms in the country for future correlation with the rate of growth and the yield of crops. The preliminary investigations will aim at the selection of the best methods and their standardization for measurement of solar radiation, evaporation, soil temperature and soil humidity, so that these data may eventually be systematically maintained besides those of wind, rainfall and the humidity and temperatures of air. The other research work will be mainly in connection with the meteorology of the air layers near the ground and the flow of heat and water through its surface. It will be one of the objects of the new branch to interpret the needs of the farmer to the forecasting section of the Department and assist him with such useful data as warnings of adverse weather like frosts, heat waves, cold waves and heavy rainfall, so that he may take protective measures in time when possible. Weather forecasts, if supplied to the farmer, will be of great value to him in his operations. By close co-operation with the Agricultural College at Poona it is expected that a model agricultural meteorological station will be opened during the first year. Such a provision will furnish the basis for the extension of systematic experimental work in agricultural meteorology to a few selected experimental farms in different parts of the country.

The most elevated observatory in Asia is the one at Gyantse (13,110 ft.) in Tibet, which is a meteorological station maintained by the Government of India. There were two still higher ones, at Pharijong (14,400 ft.) and Gartok (14,240 ft.), also in Tibet, but the former was closed in 1915, and the latter has been temporarily shut down.

The world's loftiest observatory is the one situated on the snow-bound crest of Monte Rosa, Swiss Alps, the second highest peak in the whole Alps. It stands at an elevation of 15,317 ft. above the sea. Here the perpetual snow gives records of extreme cold the year round.

(70) World's Highest 'Bubbling Spring'—the spring at the famous shrine of Kédarnath, Himalayas } 11,753 ft.

Note

In this spring, says a writer, 'every few seconds large bubbles of gas rise up through the clear water. Kédarnath stands on the bank of the Mandākini river.

In the Himalayan region referred to there are other important springs besides those already mentioned. Some are situated at the shrine of Triyugi Narayan. Four lie near the village of Tapōban, 9 miles from Jōshimath, the winter seat of the Rāwal or High Priest of Badrinath and one of the four Maths established in the Himalayas by Shri Shankarāchārya, the 'Apostle of the Hills', for his disciples about the 7th century A. D. The temperatures of the water in these springs vary from 37° to 53° C. (99° to 127° F.). All the Himalayan springs are mentioned in the Kédara Khanda of the Skanda Purāṇa.

The great poet Kālidāsa, in *Raghuvâmsha,* defines a Tirtha as a holy place, a place of pilgrimage, especially on or near the banks of a sacred river *or* near a spring. The Himalayan shrines which we have mentioned are therefore Tirthas in even a wider sense, since they are all situated in the proximity of both a river and a group of springs. Our ancients thus exercised great foresight in selecting for these shrines spots close to thermal springs from which issue health-giving waters.

Hot springs occur in various other parts of India. There are numerous hot springs in the districts of Ratnagiri, Kolaba, Thana, Khandesh, Kaira and Panch Mahals and in the Province of Sindh. The temperatures of the Ratnagiri springs range from 38° C. (100° F.) to almost boiling point. The Tālukas (sub-divisions of a district) of Bhiwandi, Vāda and Māhim in Thana District contain a number of hot springs, a few of which lie in natural hollows in the rock in the bed of a river. They are submerged during the rainy season when the river is full. Their temperatures range from 43° to 58° C. (110° to 136° F.) and remain uniform. The best-known springs in Sindh are those of Lakhi near Sehwān, Lārkana District, and Magar Pir, north of Karachi. The Lakhi spring, popularly known as Dhāra Tirth, flows from the base of a steep limestone cliff, 600 ft. high, called the Dhāra Hill. Cisterns have been constructed to provide facilities for bathing. The temperature of the spring water varies between 102° and 124° F. (39° and 51° C.). The Magar Pir springs are situated amidst barren, rocky hills, their temperature

being 133° F. (56° C.). In an adjacent pool enclosed by a masonry wall are confined a number of marsh crocodiles, hence the name Magar springs. In Madras Presidency there are in the bed of the Godāvari two warm springs one of which lies in the middle of the river at Bhadrāchellam, about 100 miles north-east of Rajahmundry.

'From many springs in the Bhiwandi Tāluka bubbles of gas rise and give off a strong sulphurous odour which in one case has unromantically been described as 'the smell of rotten eggs and gun washings'. The nasty smell must be due to the gas being sulphuretted hydrogen which, being less freely absorbed by hot than by cold water, escapes in larger quantities from hot sulphur springs than from lukewarm or cold ones. The 'bubbling spring' at Kédarnath evidently differs in some respects from the other springs in the Himalayan region. Its water is highly impregnated with iron and sulphur, and it appears to be a cold spring or a lukewarm one.

Spring water containing iron and sulphur is considered to be beneficial to persons suffering from anaemia and chronic diarrhoea, and sulphurous water, both hot and cold, to be efficacious in gout, rheumatism, dyspepsia and affections of the liver and the skin. The waters of many of the hot sulphurous springs in Sindh are reputed to be beneficial in obstinate skin diseases.

There is a large group of hot springs at Rajgir, the capital of the ancient kingdom of Magadha and now a Jain place of pilgrimage in Patna District in the Province of Bihar & Orissa. They are more than a dozen in number and lie on both banks of the Saraswati rivulet. Their temperature is about 42° C. (108° F.) and they are usually hottest in November or December when the outflow is at its maximum. These springs have been found to possess radio-active* properties which Sir Jagadish Chunder Bose and Professor N. C. Nag have been studying for many years by means of a highly sensitive electrical apparatus specially constructed at the Bose Institute at Calcutta. Professor Nag especially has made extensive research into this radio-activity, detailed results of which, along with information about a number of similar hot springs in other parts of India, will be published in the next Transactions of the Institute. Many mineral springs are slightly radio-active, and such therapeutic values as their waters may have are due to their containing radium emana-

*For explanation of this term, *vide* Chapter VI, Item 1.

tion, a gas called radon. Thermal springs sometimes are so radio-active that unrestricted bathing in them has proved injurious. In America sick persons are permitted to bathe in their waters, only for periods fixed by an attending physician. Most radio-therapeutists seem to be of the opinion that waters containing radio-active substances in sufficient quantities to affect the body may be dangerous when taken internally and should never be so used except under the careful supervision of a competent physician. Professor Nag's impending report will show to what extent the Rajgir and other springs are radio-active.

In Iceland the hot springs are effectively exploited in numerous ways for the general well-being of the community. The Government and the Municipalities were authorized some time ago to take over all the hot springs in the island. In 1930 a hundred of them in its southern part were purchased along with a few farms. One of these farms has been converted into a dairy, the machinery of which is worked by steam from the springs. The experiment has proved so successful that more dairies are being built. Another farm is being transformed into a sanitarium for consumptives, as the spring waters there have been found beneficial in pulmonary troubles. The springs are also taken advantage of to provide heat for hothouses, and they have thus made possible the cultivation of various kinds of vegetables all the year round. In the neighbourhood of Reykjavik, the chief town, lie a number of hot springs which are utilized to satisfy civic needs. The water is carried to the town by pipe lines and is used to heat some of the city's dwellinghouses and also laundries; schools, hospitals and other public buildings. Besides, a warm water swimming-bath has been opened, receiving its supply from the springs at a temperature of about 90° C. (194° F.). Cold water is no doubt carried into it by another pipe to bring down the temperature to a bearable point. Through the scientific use of her springs Iceland bids fair to become in course of time agriculturally independent.

The heat of hot-spring water is variously explained. According to one theory, it may have its origin in subterranean lava. A more convincing explanation is that *meteoric* waters—a comprehensive term which includes besides rain-water other forms of water precipitated from the atmosphère such as dew in tropical regions

and snow and frost in colder regions, after penetrating deep into the earth, rise up again along fissures in the rocks underground, and acquiring the temperature of these rocks, emerge at the surface as hot or thermal springs.

Earthquakes are sometimes accompanied by strange behaviour on the part of hot springs. There was a severe earthquake in South Serbia (Jugoslavia) in March 1931. Professor Jelenko Mihailovitch, Director of the Belgrade Seismological Observatory, after a careful study of its effects, obtained confirmation of the report sent out from the affected district that several hot mineral springs in the area disappeared suddenly and reappeared hundreds of yards away in the form of geysers spouting several feet into the air and showing a much higher temperature than before. A day after the great earthquake of 8th March, the hot water returned to its original outlets but increased considerably in volume. Its temperature was then found to be about 49° C. (120°F.). Shortly afterwards the springs returned to their normal temperature of 36° C. (97°F.). Within 300 yards of these hot sulphurous springs lay a spring of cold arsenic water, which remained cold but whose volume increased enormously.

(71) Elevation of the Cave Shrine of Amarnath, Himalayas } About 12,000 ft.

Note.—Amarnath is a celebrated mountain shrine in the snows between the main body of the State of Kashmir and its Tibetan province of Ladakh. Many Hindus believe it to be the 'Abode of the Gods' and therefore look upon it as the holiest spot on the earth. Thousands of pilgrims from different parts of India visit the place every year. It is a march of about 100 miles from Srinagar, the last 40 of which are extremely difficult and often dangerous. *Serais*, which consist of stone-walled, iron-roofed huts, are provided by the State at convenient stages to within 5 miles of the cave. The route for the first 60 miles up to Pahlgam is easy. The scenery thereafter is superb. Lovely flowers grow in exuberance along the route, the large showy white peony, the flag-flower (iris), the wind-flower (anemone) and Alpine flowers, many of which impregnate the air with their sweet perfume.

The route has to be repaired every year, for, with the melting of the snow, the *serais* at all high camps are shattered by avalanches

and their roofs often carried half a mile off, the rivers become flooded and the bridges are washed away. But on this march, remarks a writer who has visited the shrine, 'the unique charm of Kashmir is typically illustrated. You could easily imagine yourself in Japan, Scotland, Canada, the Dolomites or Switzerland, until you arrive at 12,000 ft. amidst scenery which only the " Roof of the World " can show.' Here lies a glacier-fed lake named Shésh Nāg with large masses of ice floating in it. Immediately in the background rears up the massive block of Kohinur, 'Mountain of Light' (18,000 ft.), the glory of which, is seen at its best at sunset. The pilgrims regard it as their sacred duty to bathe in this lake. Sometimes one single summer brings 6,000 people to the shrine. Dozens fall victims to pneumonia. In a bad year hundreds have perished in the floods let loose by the melting snow, and once a large party of pilgrims, suspecting the good faith of their Mahomedan guides, refused to hurry back over the watershed and were entrapped on the Amarnath side by a heavy snowfall.

From Shésh Nāg the route ascends to the watershed of the Lidar and Sindh rivers to about 14,000 ft. Here the flowers are marvellous wherever the snow has melted. A steep descent of 2,000 ft. from this place leads to a large meadow, a vast camping ground, from which the last march begins. The Himalayan marmot is found here in large numbers. From this point the path climbs so sharply that no pony can be led up. The last 500 feet to the shrine are negotiated by the devotees on their hands and knees.

The cave contains only three solid columns of pure white ice, each 4 or 5 ft. high, stained with vermilion and hung with faded garlands of marigold. One remarkable feature about them is that they never melt whatever be the temperature outside, though they increase and decrease in size with the waxing and waning of the moon. It is probable that these phenomena have given rise to the ideas about the sanctity of this place. All around the cave grow 'the fairest and frailest of flowers' in every crevice, and the writer to whom we owe most of our information about this shrine loses himself in rapture as he tries to describe 'the majesty of the scenery' around and 'the sublimity of the towering shows' beyond.

(72) Volcan de Agua or Water Volcano, Guatemala, Central America } 12,139 ft.

Note.—The volcano is so called because in 1541 it destroyed the city of Old Guatemala by a deluge of water. The source of the great flood must have been a lake in the crater. The volcano is conical in shape. From its crater, which measures 140 yds. by 120 yds., stones and torrents of boiling water are occasionally discharged.

Guatemala is a volcanic country. Two other well-known volcanoes in it are Santa Maria (12,467 ft.) and Acatenango (13,615 ft.). A devastating eruption of the latter took place in January 1932. According to the brief preliminary report, it destroyed at least three towns and covered a number of other places with dense clouds of smoke and volcanic ashes.

(73) World's most elevated body of water on which steamers ply—Lake Titicaca in the Andes Region, South America } 12,466 ft.

Note.—Its length is about 130 miles, breadth 41 to 61 miles, average depth 100 ft. and greatest depth about 1,000 ft.

(74) Elevation beyond which Forests cease to grow in a dense form } 12,000–13,000 ft.

Note.—Thick forests at these elevations occur in the Himalayas alone.

(75) Elevation of Alto-Stratus Clouds ... About 13,000 ft.

Note.—These are usually thick, grey or bluish sheet clouds, sometimes forming a compact mass of fibrous appearance.

(76) World's most elevated Flying Field—La Paz, Bolivia, south-east of Lake Titicaca } 13,000 ft.

(77) Greatest Height at which Insects have been caught } 13,200 ft.

Note.—Aeroplanes are often used nowadays by entomologists to collect insect specimens at heights not previously invaded for such purposes. They have in this way caught in specially-made nets mites, gnats, wasps, flies and other insects high in the air. Balloon spiders, which are wingless insects and are thus devoid of flight power, have been captured even at 10,000 ft. above the ground. Strangely enough, the insects found at the record height mentioned above are snails, noted for their sluggishness. Glider pilots have often seen butterflies thousands of feet above the ground. This curious migration of insects into the air is ascribed to three causes:—

(1) Voluntary flight by the stronger of winged insects.

(2) Travel by certain kinds of insects, which partly rise under their own wing power and partly are carried aloft by vertical air currents.

(3) **Transportation by upward breezes in the case of the smaller and lighter insects and sometimes of wingless bugs. After they are picked up and carried to great heights, their courses are directed by the winds above the clouds.**

The power of the wind in carrying up both objects and living creatures is best illustrated by the whirlwind and the tornado. In India cases are from time to time reported of fishes having fallen from the sky during heavy thunder-storms accompanied by torrential rain. Dr. E. W. Gudger of the Department of Ichthyology at the American Museum of Natural History, has found that 'fish rains' are also caused by waterspouts which suck up fish along with water and drop them inland as their velocity decreases.

The tornado, dreaded for its destructive force, sometimes attains a velocity of as much as 500 miles an hour. The abnormally intense air movements which occur during tornadoes have been known to lift from the ground heavy objects like ploughs, hen-coops and corrugated metal sheets and to carry off roofs. A cart-wheel once came down from the sky near a village in Normandy (France)! Parts of roofs have been carried more than 15 miles away. Mr. Ivan E. Houk writes in *Modern Mechanics and Inventions* of January 1932:—

'Sometimes such winds sweep the water out of fish ponds, lift the fish into the air, and carry them many miles before they finally fall to the ground as rains of fishes. A rancher in New Mexico picked up more than a hundred cat-fish, from 6 to 10 inches long, after a heavy rain in September 1930, the fish having come down with the rain many miles from the nearest lakes or ponds. Sometimes oranges, frogs, grain and the like are picked up, transported and precipitated with the rain. There is one case on record where a young alligator, 2 feet long, came down with the rain.'

At the disastrous hurricane which swept over Belize in British Honduras on 10th September 1931, the heavy mahogany doors of the hall in Government House were wrenched off their hinges and sent flying leeward. The entire roof of the cathedral went sailing in the air, the top storey of a three-storeyed school was blown down, and a light boat was caught up in the fury of the storm and dropped at the front door of the school. Tall houses and Negro huts vanished from the landscape. In one area of the town the whole population numbering about 1,000 was wiped out.

(78) Elevation beyond which Trees cease to grow } 13,457 ft.

Note.—The only trees found at such an elevation are the poplars growing at Mangnang in Gnari Khorsum, a Province in Western Tibet. In the Andes Mountains trees end at about 12,130 ft., but in the dormant volcano of Popocatepetl (17,876 ft.) in Mexico they continue up to a little over 13,000 ft.

(79)	Most Elevated Town in the Eastern Hemisphere—Junglache in Tibet, 30° N. 88° E.	13,600 ft.

Note.—It is the second highest town in the world and stands on the bank of the river Maghang Tsan-po, the Tibetan name for the trans-Himalayan section of the Brahmaputra.

(80)	World's Largest Active Volcano—Mauna Loa, Hawaii or Sandwich Islands	13,675 ft.

Note.—The name means 'Long Mountain'. It has an enormous lava dome. Mauna Loa is not merely the largest active volcano but the largest mountain in the world in cubic content. It discharges at an eruption more lava than any other volcano in the world. For further information *vide* Chapter IV.

(81)	World's Most Elevated Town—Pasco, the seat of Silver Mines in Peru, South America	13,720 ft.
(82)	World's Loftiest Island Mountain—Mauna Kea, Hawaii Islands	13,825 ft.

Note.—The name means 'White Mountain', the summit being covered with snow. In the true sense Mauna Kea is also the highest mountain peak in the world, for, although there are scores of others higher above sea level, this peak has its base on an extensive plain 18,000 ft. below sea level and is built up from there as a single mountain, rising within a distance of 50 miles to a height of nearly 31,825 ft.—(*Encycl. Br.*, 1929). As mentioned in Item 1, the plain in question forms the lowest tract of land in the world.

The Cordillera Occidental or Western Andes of Peru presents a feature of outstanding interest somewhat similar to that of Mauna Kea. The mountains extend for some distance along the coast, rising abruptly from abysmal troughs in the Pacific as deep as 20,000 ft. This part of the Andean belt forms thus a continuous, gigantic wall—40,000 to 42,000 ft. high as measured from the ocean floor to the summit—the loftiest mountain front in the world.

(83)	'Roof of the World'—the Great Steppe or Plateau of Pamir between Chinese and Russian Turkestan, Central Asia	11 000-14,000 ft.

Note

Pāmir is the northernmost extremity of the elevated mountain plateau, the largest plateau in the world, stretching northward from Trans-Himalaya for 1,600 miles. The area of Pāmir is about 37,000 sq. miles.

Bournouf suggests, with considerable ingenuity, that the name is derived from the Sanskrit *Upa-Méru*, which means 'the land near or resembling Méru' or 'Méru Minor' or 'Lesser Méru'.

Most of the region is covered with snow for half the year, but in spring grass grows on many parts of the plateau in luxuriance. Two great rivers rise in this region. The Oxus or Amu Daria flows off to the west and the Jaxartes or Syr Daria to the north. The best-known river on the plateau is the Panjāh, a tributary of the Oxus, which is so named, according to some authorities, owing to its being formed by the confluence of five (Sanskrit *pancham*) streams.

Pāmir is actually cut up by mountain ridges extending to a height of 4,000 to 5,000 ft. above the plains into a number of smaller plateaux or Pāmirs, the most important of which, named *Pāmir-i-Shiva* or Shiva's Plateau, is of great extent and elevation. The high and rugged mountain ridges and depressed river-beds which intersect the region make it a difficult one to cross.

The chief lakes in the highlands are :—

(1) Zôr-Kool or Victoria Lake, area 25 sq. m. Elevation 13,900 ft.
(2) Little Kāra-Kool, 15 sq. m. Elevation over 13,000 ft.
(3) Boolan-Kool, 8 sq. m. Elevation over 13,000 ft.
(4) Great Kāra-kool, 120 sq. m. Elevation 12,800 ft.
(5) Rang-Kool, 15 sq. m. Elevation 12,800 ft.
(6) Yashil-Kool, 16 sq. m. Elevation 12,550 ft.
(7) Shiva-Kool, over 100 sq. m. Elevation 11,800 ft.

Some of these names are of great interest. In Sanskrit *kāra* means a heap of snow, and '*koolam*' means a pond, so that the name Kāra–Kool would mean 'a frozen lake'. Similarly, *Rang-Kool* would mean 'coloured lake'. Shiva–Kool, like the Shiva Pāmir, is obviously named after the god Shiva.

Buddhism appears to have flourished in ancient times in the Pāmir region, for the Chinese traveller Hiouen–Tsang, who visited the

Oxus countries in 630–644 A. D., says that there were Buddhist monasteries or Vihāras in the Pāmir highlands.

Most of the foregoing information is taken from the *Encycl. Brit.* (*1889*).

The eminent French savant, Quatrefages, says that, judging from what exists to-day of this vast central region of Asia (Pāmir), it may be regarded as having included the cradle of the human race. This view, says Dr. William Warren in *Paradise Found*, has been widely accepted by mythologists, comparative philologists and archaeological ethnographers. Among the most distinguished supporters of this view may be mentioned Professor Max Müller and Sir S. Radhakrishnan.

In his *Indian Philosophy* Radhakrishnan says that the Védic Aryans and the Iranians lived originally in Central Asia as one undivided race till the necessities of life, want of room and a spirit of adventure impelled them to leave their common motherland in search of a new home in different directions. The history of Indian thought, he adds, begins only when the Central Asian Aryans divided themselves into two groups, the one coming down through Afghanistan to India and the other spreading over the country known as Iran. When the Aryans entered the Punjab, they found the aborigines of India, whom they called Dasyus, opposing their free advance.

While a large number of Western and Oriental savants hold that Pāmir was the scene of primeval paradise or original homeland of the Aryans, there is another important school of thought which strongly contests this view. It is maintained by this latter class of writers that there is ample Védic and other evidence to show that the cradle of the Aryan race lies in Aryavarta or Saptasindhava, the famous Land of the Seven Rivers, the modern names of which are Ganges, Jumna, Saraswati (now dried up), Sutlej, Ravi, Chenab and Indus; that it was from this ancient land that the Aryans migrated to other countries and continents; that they colonized even the Arctic regions over 200 centuries ago and established an extensive colonial empire, and that, owing to the love of the Arctic colonists for their motherland, the latter kept up constant communication with Aryavarta which they used to visit from time to time. This theory is either advanced or supported by well-known Western scholars like Count Bjornstjerna, Mons. Delbos, Sir Walter Raleigh and Colonel Tod. The most exhaustive work on this subject which

we have come across is *The Aryavartic Home and its Arctic Colonies* by Mr. N. B. Pavgee, in which the author says :—

> 'It seems that, while science favours the idea of the Orient having been the cradle of the Aryans, not to say of the whole human race, the Védic testimony supports the theory of the Aryan cradle in Aryavarta or the Land of the Saptasindhus or Seven Rivers. For instance, in Rig-Véda, the tract of Aryavarta, watered and traversed by the rivers of the Punjab, and lying between the Indus and the Saraswati, appears to have been designated as the "God-fashioned Region" or the Land of God and the Scene of Creation.'

In his *History of the World*, Sir Walter Raleigh strongly supports the general Hindu view regarding the cradle of mankind and adds that India was the first country to be inhabited on the earth.

Mr. Har Bilas Sarda in his *Hindu Superiority* quotes from Vyāsa's *Harivamsha* a reference to Hindu colonization of the northern country of modern Siberia, where it is said the Hindus established a kingdom with Bajrapur as its capital. It is further stated that when the ruler of this new kingdom was slain in battle, the three sons of Shri Krishna Chandra with a large party of Kshatriyas and Brāhmans, proceeded to that country and the eldest son was installed on the throne as the successor of the dead king and that on the death of Shri Krishna Chandra his sons paid a condolence visit to Dwārka. Mr. Sarda elaborates this theme of Hindu migration by a number of quotations from Colonel Tod's *Rajasthan*. We reproduce one or two of these :—' The sons of Krishna eventually left the Indus behind and passed into Zabulisthan, and peopled those countries, even to Samarkand.' ' The annals of the Yadus of Jaisalmer state that, long anterior to Vikrama, they held dominion from Ghazni to Samarkand: that they established themselves in those regions after Mahābhārata or the Great War, and were again impelled on the rise of Islamism within the Indus.'

The distinguished French astronomer, Mons. Bailly, in his *Histoire de l'Astronomie Ancienne*, says :—' In Siberia and generally below the 50th parallel of latitude and between long. 80^0 and 130^0, are found visible signs of the country having once been inhabited by a civilized race; the ruins of several towns which appear to have been at one time prosperous; manuscripts written on pieces of silk, ... and human figures carved in gold, silver and bronze. The human figures were representations of Indian deities.' In another

place he quotes a certain 'M. de P.' who, speaking of Indians, made the following remarks:—'The most terrible of all their penances was that which made them go on pilgrimage to the pagoda of the Grand Lama. They go even to Siberia, so that these Indians have been seen going there on foot, carrying water and provisions from Calicut as far as Selinginskoi in Tartary.' Commenting on these remarks, Bailly observes:—'The Indians themselves say that the Brāhmans came from the north. Can we not in fact take it that these pilgrimages are a homage which the religion of the Indians pays to the country in which it was born?'

But data from numerous sources have been collected by Sarda and Pavgee, especially the latter, in support of the theory that the original nursery of mankind and of the Aryan race was Aryavarta itself, the Land of the Seven Rivers, and that this was the centre from which the Aryans subsequently migrated to other lands on the globe. It is possible to explain on the basis of this view the Hindu or quasi-Hindu names of some of the places on the plateau of Pāmir and the references quoted above from Bailly's work. The Aryans might have colonized among other countries vast tracts of Central Asia in the remote past, as appears from some of the facts already mentioned, and such relics of Hinduism as have been or may still be found there, whether objects or names of places, may date back to the days of Hindu colonization of those regions. The Indians who, according to Bailly, used to travel on foot from places as far south as Calicut in Malabar to countries so distant as Tartary, were probably merchants travelling abroad for trade.

We have dealt so far with two theories regarding the original home of the Aryans: first, that it was the Pāmir region of Central Asia, and secondly that it was that part of India which we now know as the Punjab. There is however a third and very important theory propounded at great length, probably for the first time, by that great Indian political leader and savant, Bāl Gangādhar Tilak, in his learned work *The Arctic Home in the Vēdas.* He mentions the existence of references in the most ancient books of the Aryan race, the Vēdas and the Avesta, showing that the primeval Aryan paradise, the happy land of Airyana Vaējo as the Avesta calls it, lay in a region far north where the sun shone only once a year, a region which was in later times rendered uninhabitable by the inclement

climate due to the invasion of snow and ice. The Védic and Avestic traditions, says Tilak, have been found trustworthy when examined in the light of comparative mythology and geological and archaeological researches, and these traditions fully prove that the ancestors of the Védic Aryans lived in the interglacial period in the Arctic region somewhere round about the North Pole, which is considered by many great scientists as the most likely part of the world where plant and animal life first originated and where alone a dawn of 30 days' duration would be an astronomical possibility. After the destruction of this Arctic home by the last glacial epoch, the Aryans migrated southwards, and settled at first in the northern parts of Europe *or* on the plains of Central Asia. This migration thus took place at the beginning of the post-glacial epoch, that is about 10,000 years ago. Elsewhere in his book the author states that the Avesta contains some important passages directly bearing upon the question of the migration of the Aryans from their home in the far north to the regions watered by the Oxus, the Jaxartes or the Indus. 'It was on these plains (of Central Asia) we are told', adds Tilak, 'that our oldest ancestors gazed upon the wonders of the dawn or the rising sun with awe and astonishment, or reverentially watched the storm-clouds hovering in the sky to be eventually broken up by the god of rain and thunder, thereby giving rise to the worship of natural elements and thus laying down the foundations of later Aryan mythology.'

(84) India's most elevated Lake—Tsho Marari in Rupshu District, Ladakh Province, Kashmir State, 33° N. 79° E. } 14,900 ft.

Note.—Its area is 15 m. by 5 m. It is landlocked and the water is brackish.

(85) Highest Altitude at which Birds have attacked Aircraft } Over 15,000 ft.

Note.—According to a report in the *Times of India* of 11th April 1932, while Mrs. Griffith Lloyd, a well-known Canadian woman flier, and Mr. Stuart Wandell, a skilled mountain pilot, were flying over a peak of the Rocky Mountains 15,000 ft. high, they saw below them two giant eagles attacking a flock of mountain sheep. Mrs. Lloyd, who was in charge of the controls, 'nosed down, roaring over the birds to frighten them from their prey.' 'Believing the man-made

bird intended to rob them of their meal, the two eagles charged. They narrowly escaped hurtling into the propeller, and one bird brushed low over the cockpit, striking Mrs. Lloyd, who momentarily lost control of her machine and nose-dived several hundred feet. Finally, convinced that the angry eagles, continuing to attack the machine, would wreck it unless the battle ended, Mrs. Lloyd turned the machine and fled, leaving the screaming birds circling above.'

A description of a fierce duel in the Indian sky in 1931 between man and a bird of prey appeared at the time in the local Press. As the Roumanian Prince Antoine Bibesco was flying with three other airmen from Allahabad eastward on 17th April that year, they encountered a vulture which with a shrill whistle swooped down on the invader of its domain, but by skilful manoeuvring Major Burduloiu, the first pilot, evaded it. The bird made a fresh charge and this time so damaged the left wing of the aeroplane as to put it out of action. The vulture was killed in the duel but not before it had crippled the 'plane so seriously as to make a forced landing essential for safety. The machine crashed on a field between Benares and Gaya and caught fire. The airmen were badly burnt. One of them, the second pilot, subsequently died, but the others recovered from their burns. At an interview to the Press in Bombay prior to his return to Europe, the Prince gave a few further particulars of this aerial battle. The machine was flying at 6,000 ft., when the vulture fell upon it from a tremendous height with such force as to tear the metal wing of the aeroplane. The bird must therefore have swooped down from a point higher than 6,000 ft.

A somewhat similar experience was met with by an airman in England on 24th April 1931. He was flying at a speed of 100 miles an hour and had just plunged into the clouds 5,000 ft. over London, when a large bird rushed at his machine and struck the propeller, and he had to make a forced landing on a cricket pitch. The aeroplane crashed and overturned, but the airman escaped unhurt.

On 13th August 1931 while a Flying Officer of the Royal Air Force in India was returning in his machine from Delhi, he met a huge vulture at a height of 2,000 ft. The bird threw a challenge to the invader of its territory by dashing against the aeroplane. It was shot dead. In spite of the heavy weight of the dead bird on the wings of the machine, the airman continued his flight.

During the Duchess of Bedford's return flight from India in August 1929, an enormous flock of Egyptian vultures was encountered at a height of 8,000 ft. between Aleppo and Sofia. At one moment it was feared that the aeroplane would collide with them, but when within a few feet of the machine, the birds dispersed on either side.

(86) Highest Elevation at which Cultivation is carried on .. 15,200 ft.

Note.—There is a cluster of small villages at this elevation in Tibet named Ombo, 32°N. 87°E., where barley is cultivated. The highest elevation in the tropics where cultivation is carried on is a little over 14,000 ft., the region being the part of Northern Andes in Venezuela lying between the little towns of Merida and San Cristobel. For several thousand feet on steep, rock-strewn slopes of the mountain up to its summit, wheat is grown by the local Red Indians. Owing to the high elevations, tropical heat is wholly absent in this region though it lies so near the equator, and the higher peaks here are covered with perpetual snow.

(87) World's most elevated Gold-field —Thok Daurakpa in Tibet, 32° N. 86° E., the centre of a large gold-field and an important settlement 15,300 ft.

Note.—Tibet is rich in gold as all the rivers which rise in it wash down sands impregnated with gold. Gold-digging as an industry has been in existence in this country from very ancient times. Herodotus, Pliny, Megasthenes, Nearchus and other ancient writers make mention of the alluvial gold dug out in Tibet, though they were totally ignorant of the agency which dug it out of the soil. Through the misinterpretation of a Sanskrit word they formed the impression that huge ants—they even add that these ants were larger than foxes !—used to dig out and heap up auriferous sand and that it was out of these heaps that the large quantities of gold available in India in those times were produced. Pliny says that 'the horns of the gold-digging ants were preserved in the temples of Hercules at Erythral' ! Professor V. Ball, an eminent geologist, has discovered that the 'huge ants' were none other than the Tibetan miners and their dogs and that the 'horns' were the gold-diggers' pickaxes. He learnt on inquiry that the gold-miners in the Province of Ladakh, which formerly belonged to Tibet but is now administered by the Indian State of Kashmir, were still using primitive implements which are made by mounting the horns of wild sheep on handles.

Besides Thok Daurakpa and Ladakh the Tibetans have evidently been working gold-fields in other parts of the country, for we learn that there is an abandoned gold-mine near a desert plain between Mānasarōvar and a place called Barkha, a distance of 5 miles from the lake on the way to Mt. Kailās in the Himalayas.

The contrast between the conditions under which the Tibetan gold-miner and his confrère in other parts of the world are working, is not without interest. The operations of the one are carried on at an elevation of nearly 3 miles where the climatic conditions are almost ideal except of course in winter when the Tibetan miner suspends work owing to snowfall and piercing cold. On the contrary, the subterranean worker in the deep mines of South Africa and elsewhere has to work well over a mile underground and requires protection from the roasting heat to which he is exposed. (*Vide* Chapter I, Item 18). Besides, the Tibetan miner has not to face such terrible dangers as rock-bursts which take a periodical toll of life in Kolar Gold Fields and other deep gold-mines.

(88) Elevation of the World's Deepest Active Crater—Rucu-Pichincha, Andes Range, Ecuador, South America } 15,827 ft.

Note.—This crater is a funnel-shaped basin, 2,500 ft. deep, 1,500 ft. wide at the bottom and upwards of a mile broad at the mouth. The inner sides in some places rise perpendicular from the floor of the pit. Two adventurous travellers descended to its bottom over 60 years ago. At its eruptions the volcano discharges dense masses of black smoke and large quantities of fine sand.

(89) Altitude of Alto-Cumulus or Medium Clouds } 10,000-15,840 ft.

Note.—They consist of large white or greyish balls of dense, fleecy cloud frequently lying close together. These fleecy balls are grouped in flocks or arranged in rows. They merge into the Cirro-Cumulus (Item 119).

(90) World's most elevated Religious Settlement—the Rongbuk Lāmasery situated in a valley of the same name in the Himalayas } 16,000 ft. = 3 m. 53 yds.

Note.—It is a big Buddhist monastery in Tibet on the way to Mt. Everest from the Tibetan side.

(91) World's Highest Group of Thermal Springs—some of the springs in Tibet } 16,170 ft.

Note.—These springs, according to Surgeon-General Balfour, issue from the level plains near a rivulet at Chung-leng at the elevation mentioned, their temperatures varying from 50° to 54·5°C. (122° to 130° F.). There are a vast number of hot springs in Tibet in the lake region, which are widely distributed between the Himalayas and Lat. 34° N. Some are situated near the village of Duchin in Little Tibet and the temperature of one of these is 68°C. (154°F.). Hot springs are numerous to the west of Lake Tengri Nor and in the mountains lying east of Lake Ma-p'ham. One of them throws up water to a height of 12 ft. So intense is the cold of winter in Tibet that these springs are sometimes represented by pillars of ice, the hot water having frozen in spouting!

(92) World's most elevated Colony—a place in the Bolivian Province of Chinchas, South America, where some families of miners have settled permanently } 16,500 ft.

(93) World's most elevated Tableland—that of Tibet } 10,000-17,000 ft.

(94) Highest Altitude at which Locust Flights have been observed } 17,000 ft.

Note.—Locust swarms have been seen flying at this altitude in the Himalayas.

(95) World's most elevated Railway Station —Ticlio on the Peruvian Railway, South America } 17,000 ft.

Note.—South America has also the second highest motor road in the world. It is in Venezuela and runs between Merida and San Cristobal, crossing a pass of the Andes mountain at an elevation of 13,583 ft. The world's highest motor road lies in U. S. A. It starts from Manitou, a summer resort in Colorado, and leads to the summit of Pike's Peak (14,110 ft.). The late Mons. Georges M. Haardt, the Belgian explorer and leader of the Trans-Asian Expedition of 1931, crossed the Himalayas along with his companions in an automobile, the highest elevation reached in the journey being 13,775 ft.

(96) India's most elevated Glacier Lake—Deo Tal in Garhwal, Himalayas } 17,745 ft.

Note.—A glacier lake is an accumulation of water formed by one glacier obstructing the outlet of a higher one.

(97) **Highest Elevation at which Grasshoppers have been seen** — 18,000 ft.

Note.—Major Hingston, the naturalist of the 1924 Everest Expedition, found these insects at the elevation mentioned, in the Rongbuk Valley. They go there in summer. One peculiarity about them is that they are very small and are difficult to find, for on account of their protective colouring they look exactly like the rocks in the crevices of which they take shelter.

It is wonderful to find how Nature clothes certain animals, which include beasts, reptiles, birds and insects, with a protective colouring which makes it difficult for other eyes to discern them against the background of their normal habitat. The black bear of the Himalayas in a forest of dark-green pines, the snow leopard in its snowy mountain haunts, the North African lion in the yellowish-white sands around the Sahara oases, the white polar bear in the icy wastes of the Arctic, the python or boa waiting for prey from the trunk of a tree, the flat-headed, bright green snake moving about in the foliage of trees, the sand-snake in sandy tracts, lizards capable of adapting their colour to that of the tree, shrub or ground as they move about, the green parrot in the trees, moths on leaves and twigs, all these are prominent examples of animals which Nature has rendered practically immune from observation in their natural surroundings.

(98) World's Larger Lakes (50 miles or over in circumference) above 15,000-ft. elevation:—

(1) Rākshas Tal (Demon's Lake) or Rāvan-hrad (Rāvan's Heart), Trans-Himalaya, Tibet. 30° N. 81° E. — 15,098 ft.

Note.—Its Tibetan name is Tsho Lagan. It is about 50 miles in circumference.

(2) Mānasarōvar, Trans-Himalaya, Tibet, east of and about 8 miles from Rākshas Tal. 30° N. 81° E. — 15,098 ft.

Note.—The lake is so named as it was formed, according to the Purāṇas, by a mental effort of the god Brahma. Its Tibetan name is Tsho Māpān. It lies to the south of Mount Kailās and, like that famous peak, occupies an important place in Hindu mythology. To quote a writer, 'Mānasarōvar formed a beautiful feature of the elysium of the Hindus or the paradise of the god Shiva on the Holy Kailās, and is mentioned as one of the four lakes from which the gods drink.' It was at this spot, says the Mānasa Khanda of the Skanda Purāṇa, that King Bhagiratha performed the austerities by virtue of which the Holy Gangā (the river Ganges) descended from heaven.

The lake is nearly oval in shape, narrower in the south than in the north, and is about 50 miles in circumference, *i.e.*, of the same extent as Rākshas Tal. Its greatest depth is said to be 268 ft. Coveys of wild geese, water-

fowl and swans sport on its surface. Pilgrims visiting these parts bathe in its turquoise-blue waters if the weather permits. Furious winds often sweep across the whole area covered by this lake and Rākshas Tal, with the result that their waters heave to and fro as in a stormy sea and big waves dash against their banks. It then becomes difficult for pilgrims to enter the water. Sometimes the waves wash fish ashore. These are picked up by some of the pilgrims who believe in their efficacy in curing diseases. Pilgrims take away in small vessels water from Mānasarōvar, as they do from the Ganges and other sacred rivers. At one corner of the lake the water is brackish and the surrounding ground is full of salt incrustations, as is the case with many other lakes in Tibet. This fact, along with the presence of an extensive series of marine-fossiliferous formations in the Tibetan area to the north of the Himalayas, strengthens the geological theory that in this land area lay the southern part of an ocean in the Palaeozoic and Mesozoic times. For further information regarding this theory, *vide* Item 122.

There are two or three Gompas or Buddhist monasteries of the Tibetan Lamas on the high banks of Mānasarōvar. Jiu-Gompa is perched on a hillock half a mile north of the lake. Near this monastery runs a stream, about 50 ft. wide and 3 ft. deep, which in the rainy season becomes a channel about 4 miles long connecting Mānasarōvar with Rākshas Tal.

(3)	Tsho Zilling, 31° N. 89° E.	15,125 ft.
(4)	Tengri Nor or Nam-cho ('Sky Lake'), 30° N. 90° E., about 150 miles in circumference or about 1,000 sq. m. in area	15,190 ft.
(5)	Taschi Bhup, 33° N. 85° E.	15,289 ft.
(6)	Tsho Tigu, 29° N. 93° E.	15,485 ft.
(7)	Schigatai, 35° N. 87° E.	16,240 ft.
(8)	Antilope Lake, 36° N. 87° E.	16,470 ft.
(9)	Tsho Horpa or Hospa, area 118 sq. m., situated near the Lingshi plain on the Kashmir frontier, 35° N., 81° 30′ E.	17,390 ft.
(10)	Tsho Sehuru. For particulars see the next item.	

There are many more such lakes. Only the principal ones, which are all situated in Tibet, are mentioned above.

(99)	**World's most elevated Lake—Tsho Sehuru, Tibet, 30° N. 86° E.**	**18,284 ft.**
(100)	**Absolute Limit for the growth of Vegetation**	**About 18,500 ft.**

Note.—After 12,000-13,000 ft. vegetation becomes scarcer and scarcer. At the high elevation of 3½ miles it occurs only on the drier and less snowy mountain slopes of Western Tibet. Near a few of the Himalayan passes it ascends to about 17,500 ft. around the lower sides of the adjacent summits. But at such elevations vegetation is seen only in the shape of isolated plants or thin grass. Proximity to the snowline, that is, the lowest limit of perpetual snow, is an effectual barrier to the growth of vegetation at higher levels.

(101) Highest Elevation at which Carnivorous Beasts are to be found } 19,000 ft.

Note.—Surgeon-General Balfour states that on the higher slopes of the Western Himalayas in the Ladakh Province of Kashmir, up to this elevation, are found the *snow leopard* and the *lynx* besides mountain hares and marmots, and on the plains up to 17,000 ft. the wild yak, wild asses, the antelope and several kinds of wild sheep. Major Hingston, the naturalist, saw wild sheep and mountain hares wandering in the barren hills on the Tibetan tableland at an elevation of 17,000 ft. Referring to the population and fauna of Ladakh, a writer remarks:—'Not only man, but also creatures under his domination—horses, sheep, goats, fowls—are diminutive here, whereas the wild animals on the high mountains are of gigantic size.'

(102) World's Altitude Record for Solo Flights in an Autogyro or Windmill Aeroplane } 19,000 ft.

Note.—This record was set up some time between 1931 and May 1932 by the aviatrix Mrs. Putnam, the wife of Mr. G. P. Putnam, the well-known American publisher and explorer.

The Autogyro, or Helicopter as it is also called, was invented some years ago by a Spanish airman named Juan de la Cierva. In this type of aeroplane the appendages of wings remain on long poles as a pair of balancing flaps, and above them, on a mast, are feather-shaped windmill vanes which spin at a speed dependent on the speed of the 'plane. In the ordinary aeroplane air 'pockets' or bumps are felt by the occupants, and air-sickness is sometimes experienced by passengers. But in the autogyro none of these discomforts are felt as it is self-balancing. Besides, the use of windmill vanes instead of wings makes it possible for the machine to rise into the air or land on the ground almost vertically. In rising, however, it requires nearly as long a run along the ground as an ordinary aeroplane, but in landing it descends gently like a parachute, requiring no final run, and so it can land in an area measuring less than a tennis-court. Further improvements in the machine are being attempted in France and other countries with a view to permit of its similarly taking off from a small area.

One other remarkable achievement of this type of aeroplane is reported. An airman named Debroutelle, flying in an autogyro at the Orly Aerodrome in France in September 1931, succeeded in keeping the machine stationary

at a height of 1,000 ft. above the aerodrome for fully half an hour. He was aided to some extent by the fact that there was only a slight wind. The feat was witnessed by two representatives of the Aéro Club de France. This is the first time that any aircraft has been able to remain stationary in mid-air for such a length of time.

(103)	'Have a care!' warns an unearthly Voice.— *'Ceiling'* or End of One Half of the World's Air	19,140 ft. = 3 m. 5 f.

Note.—The air at this altitude is about one half as dense as at sea level.

(104)	World's most elevated and most terrific Active Volcano—Cotopaxi, Andes Range, Ecuador, South America	19,613 ft.

Note.—It is at the same time the most symmetrical volcano in the world. Its crater is over 2,500 ft. in diameter.

(105)	Altitude which Vertical Air Currents should reach to produce a Thunder-storm	15,000-20,000 ft.

Note

It has been found that thunder-storms occur only under conditions which are favourable to vertical air movements on a large scale to a height of 15,000 to 20,000 ft. The air normally gets colder with increase of altitude, but if this rate of fall of temperature is abnormal, a mass of air at the earth's surface, warmer than its surroundings, goes on rising as its temperature is greater than that of the surrounding air at every level, in spite of its own cooling due to vertical rise and expansion. Owing to this effect the temperature of the rising mass goes on decreasing until the water-vapour content is sufficient to saturate it, when thunder-clouds of great thickness are formed. These clouds vary considerably in height. Their base may be between 4,600 and 6,000 ft. above the ground and their top may lie beyond the base of the cirrus clouds. Thunder-storms are generally accompanied by torrents of rain and sometimes by both hail and rain.

Thunder-clouds produce the phenomena of thunder and lightning. Lightning is a discharge of atmospheric electricity, accompanied by a vivid flash of light, generally from one cloud to another, but sometimes from a cloud to the earth and occasionally also from the earth

to a cloud. A shaft or streak of lightning is not a mere brilliant line in space. It is a column of intensely heated air driven outwards from the path of the electrical discharge at an initial velocity immensely greater than that of sound. The report that follows the flash is caused by a sudden disturbance of the air below by a violent discharge of the electricity. As sound travels in air at ordinary temperature at a speed of about 1,050 ft. a second, while the passage of light is almost instantaneous, an observer can calculate his distance from the discharge by watching the interval in seconds between his seeing the flash and hearing the report. According to Humphreys, thunder is seldom heard more than 15 miles away, and Sir Napier Shaw states that the greatest distance from the discharge at which thunder has been heard is 25 miles.

Lightning is nothing more than a huge electric spark. A streak of lightning ranges in length from 2,000 ft. to a maximum as great as 12½ miles! The shorter streaks occur when the discharge is from a cloud to the earth or *vice versa*, and the longer shafts when the discharge is from one cloud to another. In the latter cases it travels in a tortuous path, and the total length of the shaft in consequence is considerably greater.

Various measurements indicate that the duration of a lightning discharge varies from 1/5000th to 1/625th of a second and may occasionally amount to 1/100th of a second. In his *Physics of the Air*, Humphreys remarks :—'Possibly many discharges are as brief as some of these estimates would indicate, but there is ample reason to believe that others are much longer. Thus one occasionally sees a streak of lightning that lasts fully ½ second without apparent flicker.'

The velocity of thunder-storms varies considerably. Their mean velocity per hour, says Humphreys, is in Europe 30-50 km. and in the United States 50-65 km. According to the estimates of Dr. C. E. P. Brooks, formerly Secretary of the British Meteorological Society, over the whole world about 44,000 thunder-storms occur per day, 1,800 are in progress at a given moment, and they result in about 100 flashes of lightning every second. These storms are more frequent in tropical than in other regions, but in desert countries they are exceedingly rare. Without taking into consideration the vast uninhabited areas in the polar regions, there is no place on the earth where thunder and

lightning are absolutely unknown except the arid coastal zone of Peru where no rain falls. In some parts of tropical Africa, lightning is seen on more than 200 days in the year.

The phenomenon of lightning appears in various forms: chain lightning, forked lightning, sheet-lightning, and ball or globe lightning. *Chain lightning* consists of a number of flashes repeated without intermission. *Forked lightning* is that which flashes in a zigzag line or branches like the prongs of a fork. *Sheet-lightning* is a diffused glow in the clouds caused by the reflection of light, from distant flashes of lightning, by nearer clouds. It appears like a wide, expanding stream of light illuminating the outlines of the clouds. 'Like sheet-lightning, ever brightening.'—(*Tennyson*). *Ball lightning* is a globe of light, often more than a foot in diameter, and is a slow, long-continuing discharge of electricity. It floats through the air or runs along the ground. One writer says that it sometimes rebounds like a rubber ball as it strikes the ground, and generally bursts with a bright flash and a loud explosion. According to one journal, it often enters houses, floating around with a crackling noise, but seldom does harm. A rare instance of a fatal encounter with ball lightning, which occurred in 1753, may be mentioned. Professor Richmann, a physicist of St. Petersburg, had erected a lightning-rod leading to his laboratory and was standing near it at a violent thunder-storm. Suddenly there was a flash of lightning, a luminous globe sprang from the tip of the rod and struck him on the forehead, killing him on the spot. Ball lightning is the rarest form of lightning, and of all electrical phenomena is the least understood and is still under research.

An extraordinary case of a man's throat being cut by lightning during a heavy thunder-storm is reported from Harrismith in South Africa. Medical evidence revealed that he had been struck by lightning across the throat. He received a deep wound in the throat, and his clothes were found slightly burnt and torn. In July 1932, while Professor Ferdinand Dientstl of Vienna was sitting with earphones at his wireless experimenting apparatus during a violent thunder-storm, a shaft of lightning struck the aerial, flashed through the circuit and shattered his skull. A tailor plying his sewing machine next door was bowled over and seriously injured, and a traveller in the woods had an arm torn off by the same shaft.

The interchange of electricity between the earth's surface and a thunder-cloud is carried on to a great extent by discharges from elevated objects such as lightning-rods, church spires and the ridge-poles of houses, which have projecting points or angles, and the electrical discharge is seen after dark as a faint glow at their tips. This phenomenon is observable both on land and at sea. To sailors it is known as *St. Elmo's* (San Telmo's) *Fire*. On ships it is sometimes seen on dark tempestuous nights as a faint electric flame adhering to a projecting object, particularly the mast-head and the yard-arms. When only one flame is seen, it is called *Corposant*, and when two appear, they are known as *Castor* and *Pollux*.

Lightning flashes occur in two colours—blue or red. When St. Elmo's Fire is discharging negative electricity, the lightning is blue, but if this discharge is positive, the colour of the flash is red.

In *Popular Science Monthly* of September 1931 appears a graphic account of an awe-inspiring lightning display witnessed from the Alps. Three young scientists of Berlin University had been carrying out since about 1929 experiments in drawing electricity from the skies at Mt. Generoso in Switzerland, a peak noted for the violence of its electric storms. In 1931 they made a record capture during a thunder-storm at grave peril to their lives. 'From the side of Generoso's bony-ridged slope', says the report, 'they stretched as an aerial a metallic cable across a chasm to a neighbouring peak. Threaded through cylinders of galvanized metal, this antenna resembled a string of beads for a giantess. Its knobs were designed to keep the currents from leaping from the ends. Instead, an escape was provided in an adjustable spark gap, from which the electricity could be carried to a lightning-proof cabin sheathed with metal beneath the brow of the mountain. Here were meters and other instruments to gauge the force of the electricity.' One evening the experimenters saw a storm of unusual ferocity brewing. Soon the whole area was plunged into darkness. Peals of thunder followed. The daring scientists made haste with their instrument tests. Then with a violent rush of wind up the valley, the storm burst in all its fury. 'Tongues of electric flame played about the rocks of the mountain's face near the summit. Filled with metallic ore, it was a natural lightning-rod. Great yellow sparks snapped every second across the spark gap. The pointers of the voltmeters within the

cabin were doing a dance. Then came a brief lull, ominous in its calm. Suddenly a terrific thunder-clap seemed to shake the whole mountain. The valley was lit up as by a million arc lights and fantastic reflections danced over the white faces of the scientists. A bolt of flame crashed across the spark gap.' For the first time in the history of science was captured a thunder-bolt of 18 million volts! A part of the apparatus used in the Generoso tests was a 'strange network designed to carry the enormous voltage to the laboratory, where the scientists waited in danger of instant death.' Even greater voltages up to 30 million are said to be in sight. It may be mentioned that the highest electrical tension produced in a laboratory is 10 million volts.

What may be the ultimate object of these repeated experiments which involve playing with death? While it is possible that these physicists are only studying the phenomena of atmospheric electricity in greater detail than has been done hitherto in order to add to the world's knowledge on the subject, it is difficult to believe that they have not a higher end in view, but until fuller information regarding these experiments is forthcoming, it is premature to make any definite conjecture on the point.

The artificial production of 10 million voltage above referred to was achieved in the summer of 1932 at the High-Voltage Engineering Laboratory attached to the General Electric Company's Works at Pittsfield, U.S.A. It is said that its production was accompanied by a thunderous crash. The machine which produced this man-made lightning discharge of unprecedented voltage was designed by Mr. F. W. Peek (Jr.), the Chief Engineer of the Laboratory, and has been developed under his direction. The maximum current delivered during discharge after the air resistance has been broken down is 50,000 ampères. It is not khown yet to what uses this artificial high-voltage discharge can be put hereafter. For the present it is to be used for the modest purpose of research on natural lightning, the effects of which it can approximate more closely than has hitherto been possible. But powerful as this new apparatus is, its dischatge amounts to only a fraction of that of real lightning, for the highest voltage of a natural lightning discharge is 100 million and the discharges may have a maximum amperage of 100,000.

A short explanation may now be given as to how the electricity in a thunder-storm originates. In thunder-storms there is a strong vertical current of air, whose velocity in the centre or core of the cloud often exceeds 8 metres (26 ft. 3 in.) per second. In consequence rain-drops, whether large or small, are blown upward and broken into droplets in the core. They then coalesce again and fall, but are once again blown upward and broken up. From observations of these strange processes in thunder-storms, made during the first decade of this century, Dr. G. C. Simpson, then an officer of the Indian Meteorological Department and now Director of the British Meteorological Office, was led to consider that the generation of electricity in a thunder-storm must in some way be connected with the breaking of the rain-drops. He accordingly reproduced the processes in the laboratory of the Meteorological Office at Simla in 1908-10 and made the remarkable discovery that, as the water-drops broke up in a vertical blast of air, they became charged with positive electricity and the air with negative electricity. According to these experiments, then, the core of a thunder-cloud should have a distribution of positive charge, and the negative charge would be carried by the air current, both at the front and rear of the cloud as well as above.

In two papers published respectively in the *Quarterly Journal of the Royal Meteorological Society*, Vol. LVI, July 1930, and the *Philosophical Transactions of the Royal Society*, Vol. 231, 1932, Dr. Banerji has shown, as the result of extensive observations carried out by him at the Colaba Observatory at Bombay of overhead thunder-clouds, that they can be classified into two distinct types which he calls 'unitary type' and 'double type'. He has found that in a moving thunder-cloud of the former type the front part has a distribution of negative charge, the core one of positive charge and the rear that of negative charge. In a thunder-cloud of the double type this sequence is repeated. The lightning discharges originate in the region of the central positive charge and extend to the negative charge above or that at the front or rear of the cloud. Sometimes the discharges may also occur between the positively or negatively charged portions of the cloud and the positively induced charge over the earth's surface. Banerji's investigations therefore support the 'breaking-drop' theory of the origin of electricity in thunder-storms.

Observations show that the earth's surface is not electrically neutral but has a small excess of negative charge. It has also been found that a feeble positive electric current continuously passes from the air into the earth. Unless there was some agency for maintaining this charge, the air-earth current would neutralize it in a few minutes. For its maintenance therefore, it is necessary that the earth's charge should be replenished at the rate of 1,000 ampères at a time. Banerji's observations suggest that, on the average, thunder-storms transfer to the earth's surface a larger amount of negative electricity than positive. Considering that at a given moment there are about 1,800 thunder-storms in progress over the whole world, a larger amount of negative electricity is probably transferred in this way to the earth's surface and maintains its negative charge.

When lightning strikes a loose sandkill, the sand along the path of its discharge below the surface is sometimes fused into a glassy tube-shaped formation called *fulgurite* (Lat. *fulgur*, lightning). These vitrified tubes are sometimes nearly half an inch in diameter and are more common in dry sands. When vertical, as is often the case, they run for several feet underground, sometimes branching and forming a fulgurite tree beneath the sand. When a tree is struck by a powerful shaft of lightning, the amount of steam generated by its passage through the live tissues is at times so great that the whole tree is blown to pieces. The destructive power of lightning, as is well known, is terrible. Forest fires are often due to it. In 1926 it set ablaze oil tanks in the Californian oil-fields, causing a loss of 20 million dollars. The most destructive lightning on record is probably that which occurred on 10th July 1926 at the Naval Ammunition Depôt at Lake Denmark, New Jersey, U. S. A. It was followed by a succession of explosions which resulted in the death of 31 persons and injury to hundreds and damage to property estimated at 93 million dollars.

(106) Lowest Altitude of Cirrus Clouds—the highest of all forms of cloud } 20,000 ft.

Note.—These are thin and wispy, generally white in colour, and looking sometimes like carded wool, sometimes like a brush or broom, and sometimes like curly or fleecy patches. They are often popularly called 'cat's whiskers' or 'mare's tails'. They are formed at the higher levels of the atmosphere where the temperatures are excessively low, usually -22^{0} to -58^{0} F. (-30^{0} to

-50° C.), and they are consequently tenuous. At such altitudes the water-vapour content of the air is very small, but even this little in most cases condenses to form minute icy needles or crystals, or sometimes tiny snow-flakes. Practically all the other clouds are composed of droplets of water. Cirrus clouds may be seen floating above the top of high mountains. In tropical latitudes, thunder-clouds sometimes reach the level of the cirrus. When seen in wet weather, cirrus clouds will be found transformed into cirro-stratus.

(107)	Highest Elevation at which a Beast has been found to live without harmful effects	20,000 ft.

Note.—Capt. J. B. L. Noel says that the 'slow-moving, grunting yak, the ox of Central Asia' can live at this elevation. He remarks that it dies if brought down too quickly even to 8,000 ft. above sea level.

(108)	Point at which Altitude Flier generally begins to use oxygen	20,000 ft.

Note.—Owing to the low density of the air at such a level it usually becomes necessary for the aviator to breathe artificial oxygen, for which purpose he carries oxygen apparatus. Some fliers commence its use at a few thousand feet lower.

(109)	Most elevated Mountain Peak in North America—Mt. McKinley in the Alaskan Range	20,300 ft.

Note.—The most important feature of this peak is that, with the exception of Mauna Kea (Hawaii Islands), it rises to a greater height above the surrounding country than any other mountain in the world.

(110)	Highest Elevation at which Tracks of Beasts have been noticed	Over 21,000 ft.

Note.—The tracks of mountain hares and foxes have been seen at this elevation by Col. Howard Bury during one of the Everest expeditions.

(111)	Greatest Height at which the noise of a railway train has been heard	4 miles

Note.—As early as the sixties of the last century it was found by the aeronaut, James Glaisher, by means of repeated balloon ascents in England, that terrestrial sounds were more or less audible according to the amount of moisture in the air. In one of these ascents the balloonist heard the noise of a railway train when he was in clouds at a height of 4 miles, but no sounds reached his ears at the same height on another occasion when the clouds were far below him. The explanation for the variation in the audibility of sound in this case is that the lesser the density of the gaseous medium, the greater is the velocity of sound in it. Thus in hydrogen, the lightest of gases,

sound has been found to travel at 4,166 ft. a second, while in carbonic acid gas, which is about one and a half times heavier than air, the speed is as low as 843 ft. Now moist air is only a mixture of dry air and water-vapour. The latter is lighter than dry air in the ratio of approximately 9 to 14·4. Consequently, the larger the proportion of moisture in the air, the faster does sound travel. One important factor which governs the velocity of sound in air is temperature. The velocity decreases about 1 foot per second for each degree F. fall in temperature. At 60° F. the speed has been found to be about 1,039 ft. a second. At a height of 4 miles where the temperature would be considerably lower (varying with latitude), the speed would be correspondingly less. In the present case the decrease in speed due to fall in temperature must have been more than made up by the increase in speed due to the presence of a large quantity of moisture in the air.

(112) Highest Elevation at which Winged Insects have been seen } 21,000–21,500 ft.

Note.—Bees, moths and butterflies were seen at 21,000 ft. on Mt. Everest by the naturalist Hingston during one of the Everest expeditions, and a butterfly was seen at 21,500 ft. on Mt. Kāmet by the Kāmet Expedition of 1931.

(113) Highest Elevation at which a Bird's Nest has been found } 21,500 ft.

Note.—Noel mentions having seen a crow's nest at this elevation on Everest.

(114) Holy Mount Kailās, Himalayas, Tibet, north of Lake Mānsarôvar } 21,900 ft.

Note

According to Hindu mythology, Kailās is the abode of the god Shiva, and also of Kubéra, the god of riches. A Kumbha Méla or religious assemblage of ascetics and other pilgrims, who include Buddhist monks of Tibet, is held a few thousand feet below the crest of this peak once in twelve years. The place is particularly difficult of access to pilgrims from India, who have to travel hundreds of miles frequently across rugged hills and at later stages have to cross high passes. Unlike the Kédarnath and Badrinath routes, there are no rest-houses on the way. The paths are often narrow and steep, being ascents and descents lying buried in snow. In places the snow may be knee-deep and occasionally thigh-deep. Where the paths are steep and narrow, the laden mules and yaks sometimes miss their footing and go rolling down the hillside to

their doom. Certain portions of the route have to be covered on foot alone and, at some places where the track is barely more than two feet wide, crawling on all fours becomes advisable. The climatic conditions of the region cause serious discomfort and hardships. The high elevations and consequent rarefied air make the pilgrims breathe hard during a considerable part of the journey. In a few days the face, hands and other exposed parts of the body become dark, the skin begins to crack and vaseline or other unguent has to be constantly used. On the Tibetan side, owing to the absence of trees and shade, the glare of the sun is so intense that the pilgrims have to use goggles.

The majority of pilgrims travel *via* Almora, U. P. For the first few days the route lies through dense forests. Scorpions and leeches invade the camps, especially when it rains. The first place of any importance reached is Dharachal, 90 miles from Almora. The next camping place is Khéla, and it is here that the real climb of the Himalayas begins. Among the few inhabited places met with during the next few days are a fine temple and a lämasery, 12 miles south of a place called Malipa; Garbayang (11,000 ft.), a village which contains about 150 houses, a school and a post office; Thakalkote, the seat of the Tibetan Governor or Jongapan. The next halt is made at Kalpāni, a sacred place at the foot of a hill, where a spring gushes out. After Thakalkote the path throughout lies at elevations of 14,000 to 16,000 ft. The region is absolutely desolate. In the distance rise, tier above tier, lofty peaks clad in eternal snow, the most picturesque being Gurla Mandhata. On crossing the Gurla Pass the pilgrims catch the first glimpse of the holy peak of Kailās. Shortly afterwards the lakes of Rākshas Tal and Mānasarōvar are reached. In Iceland, owing to the clear atmosphere, visibility is so great that the outlines of mountains even 100 miles away are distinctly seen. For a similar reason, in these parts too, very distant objects seem to be quite close.

About 20 miles off Mānasarōvar is a place called Dharchin (14,500 ft.), the first Buddhist monastery at the foot of Kailās, where the pilgrims rest for the night. The Tibetans regard this peak with the same veneration as the Hindus do. From Dharchin the pilgrims start the next morning on a *parikrama* or circumambulation of the Holy Mount, a journey of over 30 miles round it, which

ordinarily takes two days, though the hardier of them are able to do it in one day. They have to march a long distance through a ravine at the foot of the mountain. There are two lāmaseries on the way round. After a good deal of arduous climbing over glaciers, the pilgrims reach the head of the Dolma Pass where lies the actual place of worship, Gaurikunda, a small lake, the second most elevated in the world, about 18,200 ft. above the sea. It is about 300 ft. long and 150 ft. broad and its surface is frozen all the year round. It is bounded on three sides by almost perpendicular masses of ice. Its border presents a transparent green colour. Gaurikunda is the loftiest place of pilgrimage in the world. It is unbearably cold here, and the air being rarefied — nearly one half as dense as at sea level, respiration is attended with discomfort. The pilgrims break the surface of the lake with an alpenstock or by stone-throwing and take out water for their ablutions and prayers. In rare cases, a daring devotee ventures to take a dip and immediately comes out shivering all over. Few prolong their stay at this extremely cold place beyond an hour or so, and pilgrims depart immediately after performing their rites and ceremonies. They return to Dharchin down steep snow-covered paths. Here ends the pilgrimage.

It may be asked how it is that on great mountain heights where the distance of the sun is reduced by a few miles it is much colder instead of being warmer than in the valleys down below or at sea level. Our globe takes up heat from the sun and then radiates it back into its vast gaseous envelope, the atmosphere. The layers of air nearest to the surface of the earth are warmed mainly by this radiated heat, and the farther up the layers of air, the less will be the amount of such heat absorbed by them. Consequently, the higher a place is above sea level, the lower will be the temperature there, until after a certain elevation, which varies with latitude, the drop in temperature causes the mountain to be mantled in perpetual snow. It has been found that, on mountains, the temperature of the air falls at the rate of about 1^0 C. for every 590 feet increase of elevation.

Swāmi Déshikānanda of the Shri Ramakrishna Mission, who has visited Kailās and to whom we owe much of our information, tells us that its top is a gigantic dome of ice. The last Méla at Kailās was held in July-September 1930. During this period pil-

grims came in parties from time to time and returned after performing their rites and ceremonies at Gaurikunda and completing a circuit of the peak.

The Maharaja of Mysore made a pilgrimage to the sacred lake of Mānasarōvar and this Holy Mount in July 1931.

The name Kailās has a special meaning in the Tibetan language, *viz.*, 'icy' or 'crystalline'. It is pronounced as *Kélās*, a compound word, *Ké* meaning 'water', and *lās* 'to shine'. The Tibetans call this peak by the name of Kélās Gangri, meaning 'icy mountain', or Kang-Rimpoche.

The Indus has its source in the western glaciers of Kailās, and the Sutlej, one of its principal tributaries, rises in its southern glaciers.

(115) Snowline in different parts of the World } Sea level to 22,000 ft.

Note.—The snowline at about 75° N. or S. latitude is at sea level; in Lapland, at an elevation of about 4,000 ft.; in the Alps, at about 9,000 ft.; on the east side of the equatorial Andes, at about 16,000 ft.; on the west side of the equatorial Andes, at about 18,500 ft.; on the side of the Himalayas facing India: varying from about 14,000 ft. on the eastern part of the range to 19,000 ft. on the western; on the side of the chain facing Tibet: varying from about 17,000 ft. to 22,000 ft. east to west.

(116) Highest Elevation at which any living creature has been found to dwell } 22,000 ft.

Note.—The tiny Attid Spider described by one writer as 'a minute and incongruous black spider', and the Carabid Beetle, which have been found on Mt. Everest, are the only two creatures dwelling at such a high elevation. Many writers give the elevation as 24,000 ft., but we are accepting Noel's figure, as he gives an almost detailed account of everything discovered during the Everest expeditions.

Commenting on the discovery of animal life in such inhospitable regions, the naturalist Hingston exclaims:—'How relentless is the force of Nature to spread into every corner of the earth !............I saw life thriving in ice pools, glacial crevasses and rock-bound mountain passes.'

The reader has now had some picture of animal life—on the earth's land surface at as high an elevation as 22,000 ft., and in the ocean at as great a depth as 24,000 ft! The land creatures mentioned above live under a pressure of less than half an atmosphere, while the marine creatures support a pressure of about 724 atmospheres, nearly 1,500 times as much! And between the two is a variation in vertical distance of nearly 9 miles. Wondrous indeed are the dispositions of Nature!

(117) World's most elevated Extinct Volcano—Aconcagua, the highest peak of the Andes Range, South America — 23,080 ft.

Note.—The summit of this peak was first reached by mountaineers in 1897.

(118) Highest Altitude at which a Giant Bird has been seen flying — Over 24,000 ft.

Note.—It is the Lammergeyer or Bearded Vulture, a large bird of prey inhabiting the Pyrenees and the higher mountains of Africa and Asia. It measures nearly 4 ft. from beak to tail, and has a wing-spread of 10 ft. Besides eating carrion, it preys on living animals like chamois, lambs, kids and hares.

The above altitude record is taken from the 'Report on Natural History' by Dr. T. G. Longstaff appended to *The Assault on Mount Everest, 1922* by Brig-General C. G. Bruce and other members of the expedition.

Not less remarkable is the record of another great bird, a 'super-giant' compared with the Lammergeyer. It is the Condor, one of the largest known species of the vulture family, found commonly in the most elevated parts of the Andes Mountains. Its greatest expanse of wing is about 14 ft., the average being 8 to 9 ft. From their lofty haunts these birds descend to the plains only when driven by hunger, and then in pairs they successfully attack sheep, goats, deer and other animals, though as a rule they prefer to feed on carrion. The explorer, Humboldt, reports having seen a condor flying near the summit of Aconcagua at an altitude of 22,000 ft.

(119) Altitude of Cirro-Cumulus Clouds — 20,000-25,000 ft.

Note.—These are small, pure white, rounded clouds arranged in groups and often in lines. They often occur in warm dry weather.

(120) Absolute Limit to which the best of Airmen can fly and retain consciousness without using oxygen — 25,000 ft.

(121) Highest Camp established in Mountaineering *without* resort to oxygen—in the 2nd Everest Expedition — do.

(122) Highest Elevation at which Fossils have been found — 25,000 ft.

Note

Fossils were discovered at this high elevation on Mt. Everest by Mr. N. E. Odell, a geologist who accompanied the climbing party at the last Everest expedition of 1924. The commonly accepted theory about the formation of the Himalayas is that, till towards the middle

of the Eocene or first period of the Tertiary Era in geologic chronology, *i. e.*, till about 35 million years ago, the entire area now occupied by this lofty range lay under a shallow, land-locked ocean with a soft, sinking bed, which covered most of Asia during Palaeozoic and Mesozoic times. South of this ocean which has been named the Tethys Sea, was the Salt Range of the Punjab, which now lies some 80 miles south of the Himalayas. Till some time during the Silurian or third period of the Palaeozoic Age, the area covered by what is now the Salt Range lay under the Tethys Sea, but during that period the sea retreated northward and this area became dry land. By middle Eocene the Salt Range had become covered with glaciers and in those times formed the northern margin of the primeval continent of Gondwana Land. The rivers of this continent flowed northward into the Tethys Sea and poured into it their load of silt and other detritus. These sedimentary deposits went on accumulating and preserved within them large quantities of fossils, the organic remains of the marine animals of that period. About the middle Eocene certain forces, directed from the northern side and possibly generated by a violent crumpling of the earth's crust, began to push and squeeze the soft bottom of the Tethys Sea, but the Deccan tableland which formed part of Gondwana Land arrested the further advance of these forces. As the result of these tremendous pressures the floor of the sea was forced upward, and the material thus elevated formed the Central Zone of the Himalayas. After a comparative lull extending over about 10 million years, in the middle of the Miocene or second period of the Tertiary Era, came another upheaval which formed the Lesser Himalayas and also raised the Central Zone further up. This second upheaval was followed by another prolonged lull which lasted about 6 million years. Then came the third and last upheaval, which brought up the Outer Himalayas or the Siwaliks and re-settled both the Central Zone and the Lesser Himalayas at still higher elevations. It thus took about 16 million years for the whole process of elevation which culminated in the formation of this mighty range, the last upheaval having taken place some 19 million years ago. The Himalayas contain in their folds deposits of successive ages, and in the Tibetan Zone fossiliferous strata of the Primary and Secondary Epochs are largely developed. The fact that strata of marine origin are found forming part of this

chain at high levels goes to support the theory of its oceanic origin. The Dyhrenfurth Expedition to Kāngchenjunga is reported to have collected new evidence testifying to the accuracy of this theory. The fossils found some 4,000 ft. below the summit of Everest are stated to be of marine origin belonging to an age over 100 million years ago.

Gondwana derives its name from the aboriginal hill tribes, the Gonds of Central India. In modern geography it applies to the Amarakantak plateau (400 miles by 280), a part of which lies in the north-east of Central Provinces. A description of Amarakantak is given in the Matsya Purāṇa, the 16th of the 18 Purāṇas. It formed part of the ancient Province of Kalinga and is described as that part of the Vindhyas which is near the source of the river Narmada. The Vindhya mountain itself is sometimes referred to as *Jalabālaka* (Son of Water), a name which at once suggests the geological history of the range. In his remarks on the deposits of the Vindhyan region, Professor Wadia says :—

'The epeirogenic upheaval which lifted up the Vindhyan deposits from the floor of the sea to form a continental land-area was the last serious earth-movement recorded in the history of the Peninsula...........The difference in petrological characters in the Vindhyan system denotes a fundamental difference of physical geography, viz., the prevalence of a deep sea during the earlier history of the formation, and its shallowing at the time when the upper part of the system was deposited.'

The name Jalabālaka therefore brings out significantly what must be a fact—that our ancients knew the origin and evolution of the Vindhya mountains. But how far their knowledge of the geographical evolution of India extended is a subject beyond the scope of the present work.

(123) Apex of Cumulo-Nimbus Clouds ... 25,000 ft.

Note.—These clouds are massed in the form of huge mountains. Their base lies 4,600 to 6,000 ft. above the ground, and though generally their top is at 25,000 ft., the highest occasionally reach the boundary of the Troposphere.

(124) Loftiest Himalayan Summit reached by man so far—that of Mt. Kâmet in Garhwal } 25,447 ft.

Note.—Kāmet is situated more than 500 miles west of Mt. Everest and 570 miles north-west of Kāngchenjunga. It enjoys much more equable wea-

ther than either of these two peaks. Its summit was reached in June 1931 by a small British Himalayan Expedition led by Mr. F. S. Smythe, who was a member of the last Dyhrenfurth Expedition to Kāngchenjunga. The feat was achieved practically without the use of oxygen. Several unsuccessful attempts had been previously made to conquer Kāmet.

Smythe describes the panoramic view from the top as follows:—

'We were too far above the world; one's eye passed almost contemptuously over mighty range upon mighty range to seek repose in the violent hazes of illimitable horizons. Even the turreted thunder-clouds, sun-crested above, purple-shadowed below, would not attain to our level. The breeze fanning us was deathly cold, the silence and sense of isolation almost terrible. There were no green valleys; all about us were peaks of black rock and glaring ice and snow, frozen outposts of the Infinite.'

The two other lofty peaks of the Himalayas completely scaled before Kāmet were Trishūl (23,406 ft.), whose summit was reached in 1907 by Dr. T. G. Longstaff of the pioneer Himalayan party organized by Mr. A. L. Mumm, Secretary of the Alpine Club, and Jongsong La (24,340 ft.) which was climbed completely on 3rd June 1930 by Hormin and Schneider, two members of the Kāngchenjunga Expedition of that year, and two days later by Smythe in company with another.

(125) World's Altitude Record for Parachute Jumps, *i.e.*, greatest height above ground from which an airman has made a parachute leap from aircraft and landed safely	25,525 ft.

Note

This record jump was made by the French pilot Rène Machenaud near Etampes, south of Paris, about June 1932. The sealed instruments carried by the aeroplane registered an altitude of 7,780 metres (25,525 ft.). He floated down through the clouds to a spot about 25 miles south-east of Etampes and made a perfect landing 23 minutes after leaving the machine. His average speed of descent was thus 18½ ft. per second or 1,110 ft. a minute.

A parachute leap from a great height is a sensational feat. With the closed parachute harnessed to his body, the airman steps out into the void. He plunges headlong into space, just as a swimmer takes a header into water. Sometimes for the thrill of it he does not pull the release ring until he has dropped like a stone a few thousand feet, turning a series of somersaults during the fall! The world's record for such a drop is about a mile, a distance which

would take 18 seconds to fall through. On rare occasions, owing to defect in its construction, a parachute fails to open, which means certain and speedy death, but such great care is taken nowadays in its construction that the apparatus has come to be regarded as the life-buoy of the skies. Most of the accidents are due to the inexperienced jumper pulling the rip-cord before he gets well clear of the aeroplane and his parachute fouling the machine in consequence.

When a parachutist plans a leap from an altitude of over 20,000 ft., he carries oxygen equipment. During descent from a high altitude he often delights in taking photographs of himself or of objects on the ground or in broadcasting his sensations by means of a portable transmitter which he carries. When 6 to 10 feet from the ground, the parachute jumper usually comes down like a stone—one airman says it is like jumping from a wall—and on landing, he is often dragged along the ground by the expanded envelope for some distance, especially when a strong wind is blowing.

In 1925 an Army parachutist in America made an exciting and successful jump from a height of 4,820 ft. blindfolded, shackled and manacled, to show that an airman, if wounded in an aerial battle to the point of helplessness, could yet land safely by parachute.

A parachute jumper in America had a novel experience in 1928. He leaped from an aeroplane and was caught in a powerful rising air current. He remained suspended, practically motionless, 2,000 ft. above the ground. For two minutes it looked as if he was doomed to stay in mid-air indefinitely. It was his first jump. He was wondering what to do next, when luckily the updraft slackened and he descended to earth at the record speed of 3 feet a second!

A dare-devil parachute hero of the screen in America, tired of floating down from the skies in a parachute and landing without adventure, became curious to find out how it would feel to be blown over the edge of a cliff 200 ft. above the sea. He got a powerful wind machine of the kind used in the studios for producing artificial storms and fixed it at the top of a cliff near Santa Monica on the Californian coast. He spread out a parachute on the ground pointing in the direction of the wind machine, strapped himself in and turned the air on. The envelope filled, and when it became inflated like a balloon, the parachute along with the bold and curious experimenter sailed over the cliff at a speed of 40 miles an hour. The parachute

righted itself and provided the flier with the fresh thrill for which he was thirsting.

In 1930 the famous American airman, Bert White, made a parachute jump from a height of 25,000 ft. He took half an hour to descend and, although he carried oxygen equipment, he became unconscious on the way, lost a glove and had one hand frozen in consequence. When nearing the earth, he regained consciousness and released an auxiliary parachute to relieve the strain.

An ingenious device to save passengers when an aeroplane is in difficulties was recently demonstrated at Santa Ana in California, when four men were 'parachuted' from a cabin monoplane from a height of 4,000 ft. The pilot pulled a lever, when two of the passengers along with the seats they were occupying were swung outwards through doors in the sides of the fuselage and dropped into space, while parachutes, carried under the seats, automatically opened out above their heads. The pilot then pulled a second lever, and the remaining two passengers were similarly 'jettisoned'. All the four floated down safely to the ground, still sitting on their seats! The doors in the fuselage automatically open when the lever is pulled. Davits swing outward with each seat and an automatic grip drops the seat with its occupant once it gets clear of the 'plane. As the device begins to operate, a metal hand gently slips round the waist of the passenger by way of reassuring him. Another novel device, apparently meant for pilots in solo flights when the 'plane is falling or is on fire, was exhibited at Cologne by a German inventor in 1928. It is intended to avert the danger of the parachute fouling the aeroplane as the airman jumps out. This device is a compressed-air gun which lifts the pilot bodily from his cockpit and catapults him with his parachute 30 feet clear of the machine! He pulls a hand trigger, and he is shot out into space like a projectile.

In America, in 1928 a successful delivery of typewriters was made from an aeroplane in flight, by means of the parachute. They had been carefully packed in a special crate to prevent damage by jarring, and when landed were found to be in a perfect condition. Experiments in landing packages by parachute are, it is reported, also being conducted by the British Air Ministry.

During the last few years experiments have been made, especially in England and America, towards developing the parachute

for military purposes. In 1929, at the American Army manoeuvres, a machine-gun with its crew of three men was landed by parachute from a military aeroplane, and they set up their weapon and got it into action in three minutes. A detachable parachute-cabin for troop-carrying machines has been built and tested in England. When perfected, it can land a squad at a time from mid-air. The pilot pulls a lever, and immediately a small parachute is catapulted by compressed air and releases a larger one. This in turn exerts sufficient force to drag into the open air a giant parachute which lifts the entire cabin off the 'plane and brings it gently to earth, shock-absorbers breaking its fall. As soon as the cabin has left the 'plane, the machine returns to its base for another cabin. In the United States trials have been made, with promising results, of parachutes designed to bring a whole aeroplane with its occupants safely to the ground in an emergency. At one of these trials a pilot took a large machine up, released a huge parachute 65 ft. in diameter, and then jumped out with his own parachute, allowing the 'plane to come down. The trial proved a success, though the undercarriage sustained slight damage.

Japanese women are said to be more 'air-minded' than many of their European sisters. This is because they receive from their Government every encouragement possible. They receive their training in the various aviation schools in the country. They are among the pioneer women in the world to enter the field of commercial flying. These aviatrices come from different classes. There are among them girls belonging to well-to-do families, graduates and school students.

Miss Miyoko Niyamori, a young lady known as the 'Parachute Girl', caused a sensation in Japan in 1931 by being the first Japanese woman to attempt a parachute leap. In order to test a parachute specially equipped to float on water on alighting, she subsequently exhibited her skill and daring by making a leap from an aeroplane from a height of more than 13,000 ft. into the sea off Tokyo Bay. This is reported to be a record jump in Japanese aviation. Miss Niyamori is planning to organize a parachute-manufacturing concern in Japan.

It is interesting to learn that the parachute was known, though in a cruder form, in the kingdom of Siam long before its invention

in Europe. In his *History of Siam* published more than two centuries ago, Father Loubère, who visited the country as the ambassador of Louis XIV of France, gives an account of a Siamese frequently diverting the royal family by taking prodigious leaps from a tower with the aid of two specially-made 'umbrellas' fastened to his girdle. The sacred books of the Siamese also mention that in ancient times, at ceremonies attending the coming of age of the son of a ruler, trained men used to jump from the top of a bamboo tower with the help of umbrella-like contrivances with bent bamboo handles which were fastened to their sash-belts.

That India is leagues behind other countries in aviation is shown by the single fact that the first parachute jump in this country was made as recently as 9th March 1930. It was made at the Juhu flying ground near Bombay, and even then it was two British airmen of the Bombay Flying Club who made the descent.

(126) Altitude of Cirro-Stratus Clouds ... 26,000 ft.

Note.—These are thin sheets of whitish cloud, intermediate between the cirrus and the stratus, which sometimes cover the sky completely, giving it a milky appearance, and at other times present a fibrous structure. They generally consist of minute ice crystals and often cause haloes round the sun and moon.

(127) Height of the 'Homogeneous Atmosphere' 26,400 ft. = 5 miles (*Encycl. Br., 1929*)

Note.—This means that 'if the density of the atmosphere remained uniform throughout with the same value as at the earth's surface, the air would form a layer only 8 km. (5 miles) thick, and this is sometimes called "Height of the Homogeneous Atmosphere".'

(128) Highest Camp established in Mountaineering *with* resort to oxygen 26,500 ft.

Note.—This Camp was put up by Finch and Bruce in the 2nd Everest Expedition of 1922.

(129) India's Loftiest Peak—Nangā Parbat, Himalayas, Kashmir 26,629 ft.

Note.—Yet it is probably only the twelfth loftiest peak in the world. It rises in lonely and majestic splendour at the westernmost edge of the Himalayas, dominating the landscape. 'Nangā Parbat' means 'Naked Mountain', and the peak is probably so named owing to the bareness of its heights.

(130) World's Elevation Record for Load-carrying up Mountain Heights } 26,000-26,800 ft.

Note.—During one of the three attempts made on Everest in 1922 a young Gurkha non-commissioned officer of the 6th Gurkha Rifles named Naik Téjbir Bura carried a load of spare oxygen reservoirs—one writer mentions their weight as 50 lbs.—to 26,000 ft. At the 1924 expedition three porters carried loads to 26,800 ft. In both these cases the climbers relied on their inherent powers of acclimatisation and made their ascent without the aid of oxygen.

(131) Highest Altitude at which a Bird has been seen flying } 27,000 ft.

Note

A crow was seen flying near the summit of Everest by the climbing party in 1924. It is a wonder how the lammergeyer, the condor, the eagle and other birds of prey, as also the crow bear the changes of high altitude without the least ill effect. Their eyes, skin, wings and breathing apparatus must be peculiarly constituted to enable them to stand these conditions. It is not all birds that can do so. In one of his balloon ascents referred to in Item 111, the one made on 5th September 1862, Glaisher had taken six pigeons up. This is how he narrates their adventures:—

'One was thrown out at a height of 3 miles, when it extended its wings and dropped as a piece of paper; a second, at 4 miles, flew vigorously round and round, apparently taking a dip each time; a third was thrown out between 4 and 5 miles, and it fell downwards as a stone; a fourth was thrown out at 4 miles on descending; it flew in a circle, and shortly alighted on the top of the balloon. The two remaining pigeons were brought down to the ground. One was found to be dead, and the other, a carrier, was still living, but would not leave the hand when I attempted to throw it off, till, after a quarter of an hour, it began to peck a piece of ribbon which encircled its neck, and was then jerked off the finger, and flew with some vigour towards Wolverhampton. One of the pigeons returned to Wolverhampton on Sunday 7th, and this is the only one that has been heard of.'

While certain birds can fly to great heights or at high altitudes, there are others noted for long-distance flight like the albatross and the petrel. Both these birds are often seen at considerable distances from land even in stormy weather. The albatross, found near Behring Strait and in greater abundance in the Southern Ocean, is the largest and strongest of sea-birds. In a full-grown bird the length of the body often reaches 4 feet and the weight 25 lbs. The wings are

long and narrow and sometimes measure as much as 17 feet from tip to tip when spread. It builds its nest on the top of high precipitous cliffs in the smaller uninhabited islands. In feeding, it gorges itself at times with the result that it cannot fly, and then it sits motionless on the water, heaving up and down with the waves! It follows a ship for days together, now and then wheeling round it in wide circles for nearly half an hour at a time, sailing both with and against the wind without perceptible strokes of the wing, and then pursues its flight without once alighting on the sea for food or rest. One bird, released at a seaport with a message tied round its neck, is reported to have been subsequently traced across the ocean at a place nearly 2,000 miles away, more than the distance from Ireland to Newfoundland! In this case, as there was no land anywhere between, the bird must have made a 'non-stop' flight unless it occasionally took rest on the waves. Its unique powers of flight are due to its being long-winged and web-footed, a factor which enables it to fly in a smooth glide without any apparent motion of the wings. In its soaring flight it avails itself of up-currents of air of varying velocity at different altitudes. Some writers go so far as to state that, owing to these advantages possessed by the bird, it can sleep in the atmosphere! This statement however lacks confirmation.

We have it from *Popular Mechanics Magazine* of October 1932 that there is another bird, the golden plover (a wading bird), noted for its distance flights. This bird, in its migrations, may in fair weather make a non-stop flight from Nova Scotia to Colombia in South America, a distance of 2,400 miles, flying day and night!

(132) World's Mountain-Climb Record } 28,126 ft. = 5 m. 2 f. 135 yds.

Note

This record elevation was reached by Dr. T. H. Somervell and Major E. F. Norton on 4th June 1924.

Great hardships are encountered in climbing lofty mountain heights. Furious hurricanes, sudden snow-storms, the cold stabs of icy winds, low pressure of air, exposure to the sun's ultra-violet rays, frost-bite and exhaustion, all these have to be endured by the

climbers to attain or approach the goal. Sometimes clouds of snow-dust come down in layers so thick that it grows pitch-dark in late afternoon and a chilling blast follows in their wake.

At the assault on Everest in 1924, even at 21,000 ft. a temperature of several degrees below zero was registered. Frost-bite to toes and fingers is an ever-present menace owing to the cold and wet. Mountaineers wear wind helmets, cold-proof and waterproof costumes, nailed boots, and crampons (pointed plates for the foot). The glare of snow-fields is so dazzling that snow goggles have to be used to protect the eyes. The low density of the air makes, as a rule, resort to oxygen necessary after a certain elevation. But at the last attempt on Everest in 1924, Norton and Somervell made their record ascent without using oxygen. This rendered their upward progress extremely slow and difficult. Somervell, besides, suffered terribly from the effects of what is known in mountaineering circles as high-altitude throat. The extremely cold and dry air brings on a parched throat, which in advanced stages may become a danger. On the morning following the record climb, Norton woke to find himself suffering from snow-blindness. It must have been a pathetic sight to see him assisted in his blind state down difficult steeps by other members of the party.

Among other dangers which mountaineers have to face are those which arise from landslides, avalanches, falling ice-crags, loose boulders and hidden crevasses. An avalanche is a huge body of snow, or snow mingled with ice, which becomes detached from snow-covered mountain tops and slides down the mountain side or falls down a precipice. It carries masses of rock, soil and sometimes also trees along with it. The continual accumulation of snow and ice on a mountain top makes it necessary for the excess to be got rid of from time to time. An extremely small proportion of the overloaded snow evaporates, but practically the whole of the surplus is disposed of in the form of glaciers and avalanches. On the summits of high mountains vast masses of this snow sometimes stand out so finely balanced that a thunder-clap may suffice to tilt them and bring them down with a roaring crash. The mountaineer in their path is absolutely helpless. In the Alps, says a writer, even the smallest things may cause an avalanche. The vibrations produced by a passing railway train may precipitate a slide that may deal destruction unless the

driver took the necessary precautions. A falling branch, a gust of wind or even the sound of a human voice may bring an avalanche rushing down the mountain side. In the ascent of these mountains, therefore, the Alpine guides insist on absolute silence being observed by the climbing parties. This dread of the avalanche is referred to in his poem *Sohrab and Rustum* by Matthew Arnold:—

> 'But as a troop of pedlars, from Cabool
> Cross underneath the Indian Caucasus,
> That vast sky-neighbouring mountain of milk snow
> Crossing so high that . . . .
> . . . .
> In single file they move, and stop their breath,
> For fear they should dislodge the o'erhanging snows—
> So the pale Persians held their breath with fear.'

The danger of avalanches lies not only in their tremendous weight and speed, but also in the powerful winds they often generate. The 'avalanche wind', as it is called, is caused by the pressure of the thousande of tons of snow as they travel at break-neck speed down the mountain side. Sometimes this wind is as violent an a tornado. It is driven not only along the path of the snow-slip but on both sides of it, uprooting trees on either side, and the effect of an avalanche may be felt hundreds of yards away from its course. Owing to its deadly character, the avalanche is sometimes described as a 'thunder-bolt of snow'. Avalanches occur most frequently in summer when the snows on the summits begin to melt, or when great masses of snow are piled up on the mountain sides after unusually heavy storms.

Crevasses are rents, or fissures formed in the body of a glacier as it passes over a steep or uneven bed. They may therefore be either vertical or oblique in their cut. They are often very broad and where vertical as deep as the glacier is thick, and where oblique their depths of course exceed its thickness, but their walls are rarely perpendicular. Crevasses occur always as open chasms when formed below the snow-line, but frequently as concealed abysses when formed above it. In the latter case their tops are often covered with snow, and it needs a trained eye to detect the presence of these snow-bridges which are especially treacherous when thin. When the snow is fresh, the hidden crevasses are located by tapping the snow-sheets with a strong pole, but as a precaution against accidents,

which may prove fatal, mountaineers in crossing the suspected spots cause each member of the party to be held fast by a long rope to two others, for there have been instances of unwary mountaineers being entombed in such crevasses by the snow-bridge giving way.

Other lofty Himalayan peaks besides Everest ascended by mountaineers without being able to reach the crest are:—

Name of Peak	Point reached
(1) *Nangā Parbat*	22,965 ft.

N. B.— This is the loftiest peak of the Western Himalayas and stands out like a grim sentinel at the west end of the range. It rises thousands of feet sheer above the bed of the river Indus, which itself lies at an elevation of about 3,000 ft. here. Rich tropical forests cover the lower sides of this face of the mountain, presenting a picturesque sight. The eastern face abounds in glaciers. A writer describes the glories of this peak in the following terms :—

'Loveliest of all the Himalayan heights is this Nangā Parbat as seen at a distance of some 80 miles away from the popular hill-resort of Gulmarg in Kashmir. At sunrise, before the white mists begin to gather and drift up from the valleys, or in the evening when rain all day has washed the skies to a delicate clear blue, Nangā Parbat, with its highest point 26,629 ft. above sea level, seems to be raised up beyond this world of man's diminutive traffic, a miracle of ivory and opal, hardly to be distinguished from a cloud but for the clarity of outline of its peaks and ridges. Viewed at short range, as from the valley of the Indus which curves round its base on the north and west, it impresses by its mass and height and steepness more than the greater giants, more than Everest itself even, for it rises 24,000 ft. sheer up from the river, whereas they are approached and seen, for the most part, from a ground level of over 10,000 ft.'

To mountaineers Nangā Parbat is a redoubtable peak, as ascents of it are rendered extremely dangerous by sudden snow-storms, biting winds and huge, treacherous ice avalanches. A party of four British climbers who included Mummery and C. G. Bruce, assisted by Gurkha porters, made an attempt on it in 1895. Mummery, accompanied by two Gurkhas, endeavoured to explore one of the high passes on 24th August, but could not proceed higher than 20,000 ft. He was however never seen again, and it is thought probable that he was overwhelmed by an avalanche. Referring to the obstacles presented by this peak, Bruce remarks:— 'I wonder

whether Nangā Parbat will ever be climbed; it is probably as difficult a mountain as there is to tackle, for nothing but the very lightest camp can be taken high up, and even to get to one's camping places, the climbing is terrific. At present it seems beyond the strength of man.' In Nangā Parbat unlike Kāmet it is extremely difficult to find suitable camping places anywhere within striking distance of the summit. But as mountaineering technique has made great strides in recent years, it is expected that a way may be found to overcome this formidable difficulty.

A German expedition from Munich led by Herr Willy Merkl made an attempt in the summer of 1932 to conquer this peak. A camp was established at 22,965 ft. preparatory to the attack, but owing to sickness among its members the party was forced to return.

(2) *Kāngchenjunga* ... ... 24,450 ft.

N. B.—This point was reached by the Bavarian expedition of 1929 headed by Dr. Bauer. Kāngchenjunga is far more difficult to climb than Everest on account of its impregnable defences and terrible ice avalanches. In the first attempt on this peak the progress from the camp was tedious and painful and climbing 'a desperately difficult' process. Hacking steps in the icy steeps, the mountaineers heroically fought their way up, but the peak offered stubborn resistance. It even assumed the offensive with the deadliest of weapons. Colossal masses of ice broke off from the overhanging glaciers and hurled themselves thousands of feet down the granite precipices. 'A cruel north-west wind snarls at the climbers with fiendish ferocity.' The temperature went down below zero. Still they persevered. But soon came a devastating blow when an enormous avalanche hurtled down dangerously close past the main party, swept away to his doom one of their best porters and in one moment undid all their laborious work. The onslaught was renewed from another point with even greater vigour, but these efforts were equally futile. The party were ultimately compelled to retreat and the mighty Kāngchenjunga stood unconquered.

(3) *Bride Peak*, Karakoram ... ... 24,600 ft.

N. B.— The Karakoram Range is regarded as practically a continuation or offshoot of the Himalayas. The above point was reached by the Italian tourist, the Duke of the Abruzzi, in 1909.

Mountaineering expeditions have been rendering valuable service to the cause of science, as will have been noticed even from the little information we have been able to give under some items in this chapter. But, obviously, extensive and intensive explorations of mountains of exceptional interest like the Himalayas, from the stand-points of several branches of science, involve prolonged and highly organized effort and heavy cost. It is therefore welcome news that, in the beautiful surroundings of the valley of Kulu lying on the border of Tibet and between Simla and Kashmir, an institution called the Himalayan Research Institute has been established by the Roerich Museum of New York. The brilliant galaxy of honorary advisers of this Museum includes such illustrious names as Einstein, Bose, Millikan, Michelson, Tagore and other scientists and savants of world-wide fame. The main object of the Institute is to conduct a scientific exploration of the Himalayas. Though in its infancy, it has already covered a good deal of ground in the biological field. It has sent numerous specimens of Western Himalayan flora to New York, the Michigan University and the Jardin des Plantes at Paris. The New York Botanical Garden is actively co-operating with the Roerich Museum in the latter's endeavour to discover plants of economic and scientific value, particularly those of medicinal use. Besides this important work, the Institute has made a large zoological collection and has started a geological collection too. It has also set up and proposes to maintain its own local museum and research library. It is working in co-operation with similar institutions elsewhere in the world, so that its activities are really international in their character. As for the future, there is a practically unlimited field of research before the Institute in the yet unexplored regions of archaeology and allied sciences as well as in those of the natural sciences. A sure guarantee of the future success of this great scientific enterprise is the presence on the spot of its versatile organizer, Professor Georges de Roerich, well known as an explorer, artist and author.

(133) World's Third Loftiest Peak–Kāngchenjunga 28,146 ft.

Note.—The name of this peak is variously pronounced or spelt. The Nepalese pronounce it as Kāngchenzeunga, while to the Sikkimese it is known by the somewhat jaw-breaking name of Kāngden-Dzod-Ngā, 'Dzod-Nga' meaning 'Five Treasures'. We have come across yet another variation—

Kānchan Ganga—but have no information as to how this name has arisen or whether the peak is so called in any of the other Himalayan States or in any part of Tibet. The name Kāngchenjunga is of Tibetan origin and means 'the five treasuries of the great snows'.

(134). World's Second Loftiest Peak—Dapsang, K 2 or Godwin-Austen, Karakoram Range — 28,283 ft.

Note.—About 300 miles north-west of this peak, begins the great Plateau of Pāmir, the 'Roof of the World'.

(135) The *True 'Roof' of the World*—Mt. Everest — 29,145 ft. = 5 m. 4 f. 35 yds.

Note.—There is keen controversy over the question whether there is an indigenous name for this peak. The famous explorer, Sir Sven Hedin, deduces from certain records that the Tibetan name for it is Chomo Lungma ('the goddess of the country'), but the Chief Lama of the Rongbuk Monastery, it is stated, refers to this peak in his autobiography as Joma Langma ('the cow goddess'). Neither of these names has however been so far conclusively proved to apply to Everest, and besides, it is said that Tibetans living in different places around the Everest region call different peaks by the name of Joma Langma. In many books of Geography and even in the maps annexed to the *Imperial Gazetteer of India* we find it stated that Everest is also called Gaurishankar. But in 1903 it was definitely ascertained by explorers that this was the local name of another peak in Nepal over 100 miles away from Everest. We find confirmation of this in the *Encycl. Br.* (*1929*) and in many of the latest Atlases, which show Gaurishankar as a distinct peak with an elevation of 23,440 ft.

The height of Everest was first determined by trigonometrical observation in 1841 as 29,002 ft., but it was subsequently re-measured and raised to 29,145 ft.

The relation between elevation and atmospheric pressure depends greatly on the temperature of the air. On the summit of Everest, even on the 'warmest' day the temperature is never above zero, and at night it drops to as low as - 29° F. (- 34° C.). While the barometer reading at sea level is 29·92 inches or 760 millimetres of mercury, on the top of Everest it will be about 8 inches or 203 mm., so that the pressure on the 'Roof' of the Earth will be less than one-third of that at sea level. The boiling point of water at this high elevation will be about 160° F. (71° C.).

Weights of the Earth's Crust & Central Core

Having finished with the broad divisions of the earth—its interior, its ocean and its land surface, we shall, before passing on to the next

chapter, consider how the total weight of the globe is made up. We have already given the weights of the ocean and the whole earth. The estimate formed by some geologists of the thickness and density of the earth's central core has already been dealt with in our Concluding Remarks in the first chapter.

The core is described as spherical, and its radius, we find, is 1,094 miles. Its mean density is 11·5 times that of water, so that if we take the average density of the earth's material as 1, that of the core will be $11{\cdot}5 \times \frac{10}{55}$, as the mean density of the earth is 5·5 times that of water. On the well-known formula in mensuration, the volume of the core amounts to $\frac{4}{3} \times \frac{22}{7} \times 1094^3 = 5{\cdot}5$ billion cubic miles, while that of the earth is 260 billion cubic miles. Now if a sphere whose volume is 260 billion c. miles and density is 1, weighs 6·593 sextillion tons, a sphere with a volume of 5·5 billion c. miles and a density of $11{\cdot}5 \times \frac{10}{55}$ will weigh

$$6{\cdot}593 \times 10^{21} \times 11{\cdot}5 \times \frac{10}{55} \times \frac{5{\cdot}5 \text{ billion}}{260 \text{ billion}} = 290 \times 10^{18}$$

or 290 quintillion tons.

To sum up:

Weight of the whole Earth		6,593 quintillion tons
Weight of the Central Core	290 quintillion tons	
Weight of the Ocean	1·38 „ „	291·38 „ „
∴ Approximate weight of the Earth's *Crust* (used in the widest sense) extending from the surface to the boundary between the lowermost stratum of rock and the central metallic core, will be		6,301·62 „ or 6·3 sextillion tons.

CHAPTER IV

Volcanoes

We propose to give here some general information about volcanoes, together with short descriptions of the various phenomena accompanying their eruptions and brief accounts of some of the appalling outbursts on record.

A volcano (Lat. *Vulcanus*, Vulcan, the god of fire; cognate with Sanskrit Ulkā, a firebrand or meteor) may be broadly defined as a more or less conical mountain, built up of successive accumulations of materials expelled to the surface in a state of incandescence or intense heat, through an opening in the earth's crust, by pressure from the heated interior. This opening is called the *pipe*, *funnel*, *vent* or *throat*. The bowl-shaped mouth of the volcano is known as the *crater*. A volcano may also have subordinate or parasitic craters. Whole ranges of mountains have been formed by the ejected masses of molten material consolidating in course of time around the craters. In the vast system of Andes, which extends right along the Pacific coast of South America and covers, without taking curves into account, a length of 4,500 miles, the great bulk of the masses are composed of stratified rocks, but upheaval and denudation have been assisted by direct volcanic action, and these three forces have been leading factors in the formation of the range. All types of volcanoes are present in it—ancient volcanoes almost wiped out by erosion, extinct ones with or without craters, and active volcanoes.

The principal volcanic areas in the world, besides the Andean region, are Central America, Mexico, Alaska, Hawaii Islands, Japan, East Indies, New Zealand, Italy, Sicily and Iceland. About 700 volcanoes have been counted in the whole world (107 being found in Iceland alone), and of these, according to Dr. T. A. Jaggar, Director of the

Hawaiian Volcano Observatory and a vulcanologist of international eminence, 485 are active. Few upheavals of Nature excite popular interest so much as a volcanic eruption. It is so awe-inspiring and so pregnant with possibilities of relentless forces being let loose on a vast scale and working havoc all around. And the phenomena that accompany an outburst often present a singularly sublime spectacle, compared with which the manifestations of even a severe earthquake are tame. Most volcanoes have periods of activity and of quiescence before they ultimately become extinct. Vesuvius was slumbering for centuries before the great outburst of 79 A. D. which destroyed Herculaneum, Pompeii and other cities.

The materials erupted at the outbreaks are of four main classes: (1) gases and water-vapour; (2) hot water and mud, (3) lava or molten rock, and (4) fragmentary substances. The gases given off are sulphuretted hydrogen, hydrochloric acid (abundant at Vesuvius), carbon dioxide, nitrogen and ammonia, besides carburetted hydrogen, chiefly marsh gas, the principal constituent of that deadly gas, fire-damp, so commonly found in coal-mines and at times near stagnant pools. The chief propulsive force responsible for volcanic outbursts is steam, generated by water that has percolated through the earth's crust and become superheated by contact with the molten masses of magma in the interior. The constituent gases of the water or of the magma or of both, also play a part in this propulsive action along with the steam.

It is estimated by Jaggar that the world's active volcanoes belch forth every year upwards of 100 million tons of hydrochloric acid which, being discharged as gas mixed with steam, mingles with the clouds and, combining with the sodium of the rivers, forms common salt. The rivers pour out this salt into the sea which thus acquires its saltiness.

Water-vapour escapes in vast quantities from some craters and is usually mistaken for smoke. It is often expelled with extraordinary violence. At the eruption in

1902 of Mont Pelée (4,430 ft.) in the French island of Martinique, West Indies, the greatest havoc done was caused by a blast of steam which 'rushed down at about 100 miles an hour, uprooted trees, dismounted guns, tossed boulders about and tore solid houses to pieces.'

The North Island of New Zealand contains several volcanic cones, mostly mud volcanoes. Many of them are intermittently active with their numerous 'smoke-chimneys' or *fumaroles*, and vents technically called *solfataras*, which give out sulphurous, muriatic and other acid vapours. As a result of this volcanic activity the island abounds in geysers and in hot springs whose temperatures vary from lukewarmness to near boiling point. In fact the thermal activity in this area is of a most impressive character, being rivalled perhaps only in Iceland and the Yellowstone region of the United States. A plateau over 100 miles long in the middle of the island is a veritable Inferno, the scene of incessant manifestations of minor but highly spectacular vulcanicity. Sparkling geysers soar into the air side by side with streams of bubbling mud. In the Wairakei Geyser Valley a vast amount of steam rises from amidst clumps of bushes in spiral columns, bedimming the deep-blue of the sky. In the *Empire Review & Magazine* of September 1932, Kathleen Reed gives a picturesque description of the phenomena noticeable there, in the course of which she says:—

'Some characteristic has given a name to every sight. There is the Champagne Pool, gleaming like crystal as it boils perpetually; the Prince of Wales' Feathers, a spray which is marvellously like white plumes; the Devil's Inkpot, a hole of shiny black mud; the Eagle's Nest, a pit covered with a layer of sticks which have been coated white by the sulphurous steam beneath them. A patch of boiling white mud is known as My Lady's Beauty Parlour. The big round bubbles look smooth and creamy, like boiling milk. Round the edges it has caked to a yellowish crinkled mess.

'In the evening (we) visited the Karapiti Blow-hole. It was a very dark night and the bush looked black and

densely sombre. Out of a small hole in a mass of rock a great spout of steam was coming horizontally with a hollow, thunderous sound. We could feel the heat on our faces. It was not like steam, for it was a dry heat. To prove this, our guide lit several flares and cast them into the grey rush. They were not extinguished but blown forward like so many sparks. He then showed us how great must be the pressure. Some empty petrol tins which he threw into the path of the steam bounced noisily past us. This blow-hole is considered the safety valve of the thermal district, and therefore perhaps of the whole of the North Island. . . . . .

'A few miles from Rotorua is a yellowish-white patch in the landscape known as Tikitere. Here I saw the more gruesome aspects of thermal activity, their horror unrelieved by the presence of clear waters and green vegetation. "Hell in a match-box" was the description of the Maori woman guide. Cauldrons of glossy black mud, of grey oily liquid, simmer and heave, rumble and bubble. Round them the earth is cracked and broken, and looks as if it may break away at any moment.'

'Our boat glided through the warm blue water (of a lake) at the foot of steaming cliffs from which boiling springs spurt and fall in cascades.'

A few volcanoes discharge torrents of hot water at an eruption. A big volcano has a very large crater which, being sometimes filled with water, forms an extensive crateral lake. We have already mentioned Volcan de Agua as a typical example of a water volcano. There is another lake lying in an extinct crater in Southern Oregon, U. S. A., which is about 7 miles long and 5 miles broad, with a mean depth of 1,490 ft. Its water is extraordinarily blue. The lake is surrounded on all sides by lofty cliffs rising 1,000 ft. and more.

A few years ago an American Army aviator and his mechanic had a terrible experience during a flight over the dense tropical jungles of Central America. As they were flying at an altitude of about 10,000 ft. in an amphibian aeroplane and dusk was approaching, the engine began to show signs of failure. Looking below, the airman

saw in the heart of the forest a charming little lake and, after a careful survey of it from above, decided to risk alighting on its waters. As the two men neared its surface, they felt the air getting hotter and hotter. By skilful manoeuvring, the airman succeeded in landing smoothly on the lake, but what was his astonishment when he found hot spray flying to his face from the hull of his machine! Needless to say, he was alarmed, and he immediately began to take stock of his surroundings. In the gathering gloom of night he saw to his dismay high walls of rock rising sheer from the water's edge on all sides and small columns of steam rising from the lake. The terrible fact dawned upon him that he had alighted in the crater of a water volcano in the early stages of activity. The hull of his machine sank deep in the hot water. The airman and his mechanic passed an anxious and dreadful night, for, owing to the perpendicular cliffs around, they could find no place where they could pull to shore and anchor. Early next morning they repaired their motor. After taxi-ing in a circular take-off and a couple of difficult spiral climbs, the aviator succeeded in getting clear of the rim of the crater and flew to the nearest coast. He learnt later that this volcano which had been dormant for many years, was showing signs of activity.

Under Item 53 of Chapter III we have given some particulars of the great volcano of Aniakchak in Alaska. An aeroplane flying for the first time recently over its crater was sucked in by the hot gases issuing from the fumaroles and would have been completely drawn in towards the pit but for the presence of mind shown by the pilot. By a skilful dive and climb he saved himself from a fatal plunge into the sulphurous fumes. The odour of these fumes could be perceived 40 miles from the pit and even at 6,000 ft. above the crater. But in spite of this perhaps frequent manifestation of volcanic activity, the crater has been found teeming with animal life, chiefly rabbits, grouse and Kodiak bears. Father Hubbard

the geologist who led the first expedition to this crater, (*vide* Item 53 of the preceding chapter), has since made a descent into it by an amphibian aeroplane. An aviator undertook to land his machine in the crater, 3,000 ft. below its rim, and Hubbard readily accepted his offer. The party, which included a cartographer, landed on a lake at the bottom of this dizzy abyss, called Surprise Lake. In the course of exploration of the crater, the party cut a hole one foot deep in its ash bed and succeeded in melting in it tin, zinc and even copper, whose respective melting points are 232°, 420° and 1,083° C. The copper took only a few minutes to melt. The blue vapours seen issuing from a spot close by indicated temperatures still higher than the melting point of that metal.

Katmai in Alaska is a well-known peak of the Aleutian Range. At a violent outburst in 1912 its top was completely shattered, and about the same time the valley to the north-west was covered with a vast number of small fumaroles. This region is since known as the 'Valley of Ten Thousand Smokes'. Katmai also has lately been explored by Hubbard who in mid-winter found in its neighbourhood warm rivers and a warm lake, while the temperature of the air was below zero.

In the volcanic region of Leeward Islands (British West Indies) in the Lesser Antilles group there is a remarkable crateral lake on a mountain side, with steep banks. It lies at an elevation of 2,300 ft. Its depth has not been ascertained. The pressure of the gases which escape from this lake is so great that the waters are often forced up 3 feet above the normal level. The fumes are at times poisonous. The lake has come to be known as the 'Boiling Lake'.

Volcanoes which eject mud are of two classes. The true type is known as the *salse*, which erupts acidulated mud, more or less liquid. Such volcanoes are found in Japan, Sicily, Iceland and several other volcanic regions. At an outbreak which took place a few years ago, the volcano Bandai-san (6,037 ft.) in Japan discharged over

the country millions of tons of boiling liquid mud in torrents computed at 176 ft. in length per second! The second group of mud-volcanoes occurs in petroliferous areas like those of the Crimea, the Caspian, Burma and Java. They mark a decadent phase of vulcanicity. Burma has several such volcanoes. They are merely hillocks of earth which is continually thrown out through small orifices at the top. They occur in groups and are found for the most part in the Cheduba and Ramri Islands in the Bay of Bengal near the Arakan coast and to a lesser extent at some places on the banks of the Irrawady river. The largest cone stands in the heart of Cheduba Island (area 20 miles by 7 m.) at an elevation of about 1,100 ft. above the sea. These mounds erupt quantities of earth owing to the pressure of gases escaping from the internal depths. The eruptions are usually accompanied by a discharge of saline water containing a small proportion of petroleum. The water frequently bubbles up and gives off the gases which, being composed essentially of hydrocarbons, are highly inflammable. Some of these cones eject, besides earth, fragments of stone, and occasionally the gas, which is usually marsh gas, is seen aflame. These outbreaks, says Wadia, are not accompanied by heat and all the ejecta show the temperature of the surrounding air, the ignition of the gases arising from their friction with the air and not from the earth's internal heat.

Among all the exhibitions of volcanic activity the most spectacular and devastating are the lava outpourings. Lava is only a mass of magma forced out of a volcano by subterranean pressure, but in a physically and chemically changed condition. No man can ever see magma in its original state. As it wells up and the overlying pressure is relieved, the gases present in it bubble up and react with one another and with air, which results in the combustion of their hydrogen, carbon monoxide and sulphur vapours and formation of water-vapour or steam, carbon dioxide and other gases. The escape of these gases is followed by expulsion of the molten mass below, which is then called

lava. This material is poured out either in a highly liquid or in a more or less viscous state. At a terrific outburst in Iceland which took place in 1783, two gigantic streams of liquid lava poured down from a crater. One of these was 50 miles long and 12 to 15 miles broad, and filled up ravines which were 500 to 600 ft. deep! Mauna Loa in the Hawaii Islands is called the 'King of Volcanoes'. It is a bi-crateral volcano, the larger cone, situated on its flank, being 7 miles and the smaller one on the summit being more than 3 miles, in circumference. From both craters are discharged immense quantities of lava at frequent intervals. The volcano erupts nothing else. At an outbreak in 1840 the liquid lava ejected rolled onward in a stream 2 to 3 miles wide and 12 to 200 ft. deep. At last, after flowing to a distance of 30 miles in four days, the lava stream 'leaped from a basalt precipice 50 ft. high into the sea in a raging blood-red torrent.' This torrrent continued its rush into the sea for fully three weeks, heating the water for 20 miles along the coast and destroying millions of fishes. 'So intense was the glow of lava that ships saw the lurid glare 100 miles away.' At another eruption of this volcano, which occurred in 1852, a continuous 'geyser' of liquid lava from 200 to 700 ft. high and 1,000 ft. wide gushed out at the base of its cone. Similar outflows of lava from the volcano have been witnessed in later years. In 1868 four gigantic fountains of lava played for several weeks at heights of from 500 to 1,000 ft.!

In Item 38 of Chapter III we have given a short description of that boiling cauldron of the world—Kilauea. It can be viewed at ordinary times without danger. Its level rises and falls and at its eruptions the liquid lava has sometimes overflowed the rim of the crater, but the seething mass of fiery liquid never cools or solidifies. The Kilauea lake is thus a miniature sea of glowing lava comparable to that river of liquid fire in Inferno which classic authors describe and to which Milton refers in *Paradise Lost*:—

> 'Fierce Phlegethon,
> Whose waves of torrent fire inflame with rage.'

The National Broadcasting Company of America, after great hardships, has established a remote control outpost on the brink of this volcano. In December 1931 Kilauea sprang back to life after months of slumber. On the 28th of that month Mr. Ezra Crane, an official of the Broadcasting Company, took up his position two feet from the edge of the crater and, with his gaze fixed over a thousand feet below upon a scene 'that even Dante in his wildest flights of imagination would fail in describing', issued the world's first broadcast of the scenes witnessed in a live volcano:—

'Below me is a heaving lake with an area of more than 85 acres of roaring, red-hot lava. Countless tons of molten lava are bursting up from the bowels of the earth in a score of fountains. Great showers of scarlet lava are hurled into space by the invisible forces, only to return to the seething pit once more with a roar and a crash that would still the traffic at 42nd Broadway (New York) on a New Year's Eve. . . . . Let me count the fountains for you now—over there in the far corner is the greatest of them all, playing incessantly, relentlessly, 300 feet in the air. Right next in line, almost a part of the gigantic fountain, are two smaller ones, pimples in comparison, but in reality each a hundred feet high. And this way a little bit—probably not more than 300 yards or so—is a group of one, two, three, four—no—five beauties of equal size. Let us see—that makes eight, but we have just started—look at those three enormous ones playing fiercely in the centre of this lake of fire—and, oh, did you hear that roar as they exploded their tons of liquid rock? Look right down here below me a thousand feet right into the face of eternity; there is a new one, just sprung up, playing almost out of the side of the cliff, spewing itself, fiery red all over a black crust of lava, cooled for the moment on the lake surface. That makes twelve of them, but I cannot stay here all day and count fountains, for, gazing back over there where we started, there is another group of four newcomers merrily joining in the chorus of crashing rock, seething molten stuff whose endless motion seems to beat time like the surf angrily pounding upon a rock-bound coast.'

A strong wind blew for a time clouds of sulphurous

fumes and other vapours from the pit to where the broad-caster stood, and his voice in consequence grew a little husky in the course of utterance. A microphone was subsequently lowered for one minute 15 or 20 feet down the densely vapoured crater, so that the bystanders at the edge of the cliff might hear to better advantage the roar and crash of the terrific activity below. Dr. Jaggar, the volcano expert, was present and witnessed the broadcast. He had been hearing the sounds of the volcano for twenty years. He informed Crane that the temperature of the lava at the bottom of the pit was 1,200° C.

Among the lesser phenomena noticeable at an eruption of Kilauea is a fine glassy fibre-like thread which the Hawaiians call Pele's Hair, Pele being the name of the dreaded goddess of the volcano. This material is spun by the wind from the rising and falling drops of liquid lava and blown over the rim or into the crevices of the crater. Several other objects of volcanic origin are found in this mountain such as sulphur banks, pumice beds, lava tubes, lava trees and sulphur-steam baths.

A thrilling descent was made into this terrific crater in 1932 some time before October by an intrepid Japanese contractor of the locality, named Rikan Konishi. A Hawaiian young man shot his sweetheart for refusing to marry him and then plunged with her body into the crater. From its rim the bodies could be seen 1,000 feet below near the brink of the bubbling lava lake. Konishi was employ-ed to recover the bodies. He caused two platforms to be erected on the rim of the volcano at the north-east and south-east respectively. A stout cable about a mile long was stretched across the abyss from one platform to the other. Two tractors were used to lower and raise a cage which, travelling on a pulley with its occupant, would run along the cable to a point vertically above the spot where the bodies lay. Then by means of other cables and pulleys and the tractors, Konishi was tied in the cage with a cotton rope held by a slip-knot. The cage was hoisted by a winch, held suspended for a short time, then swung to

the rim of the crater and finally hung on to the cable connecting the platforms. Thereupon it began its movement over the abyss and finished the horizontal trip in twenty minutes. Next came the perpendicular descent. After its downward progress for nearly two hours, the cage landed on the sloping sides of the crater above the bodies. Konishi got out, ran a coil of rope from the cage down the slope, descended by it over the loose rocks and viewed the bodies at closer range. Returning to the cage, he took out canvas slings and, once more descending by the rope, placed the bodies in them, after which the slings were connected to the cage by ropes and the bodies pulled up. Konishi then climbed back into the cage and signalled for the upward journey. The gruesome ascent was completed in one hour. When the cage with the bodies dangling beneath it reached the cable above, it was hauled up to the rim of the crater, where spectators were breathlessly watching the whole feat through field-glasses. Boards were then stretched out to the floor of the cage, and Konishi landed safely on firm ground, successful in his perilous undertaking.

Mt. Etna (10,868 ft.) in Sicily is the largest volcano in Europe with a circumference of 87 miles. It is one of the most celebrated and longest known volcanoes in the world and figures in the ancient classical literature of Greece and Rome. Pindar, Aeschylus, Thucydides, Theocritus, Virgil, Ovid, Livy, Seneca, Lucretius, all refer to it in their works. Hundreds of subsidiary cones, small and large, are scattered over its flanks. About 80 eruptions have been recorded during a period of 27 centuries, and they have occasionally wrought havoc. In the outbreak of 1669, one of the most terrible on record, the original outflow of lava ultimately divided itself into three fiery streams which carried destruction into the villages they flowed through. The seething mass at last entered the sea as a single stream 600 yards wide and 40 ft. deep. An eruption in 1693 was succeeded by a violent earthquake which destroyed partly or wholly about 50 towns and villages and caused a loss of

between 60,000 and 100,000 lives. In 1863 Professor Fouque made close observations to estimate the total amount of steam ejected from a lateral crater of the volcano. The quantity discharged in 100 days, according to his calculations, was sufficient to yield, when condensed, 462 million gallons of water—enough to form a lake 2¼ miles long, 2,100 ft. wide and 30 ft. deep! When Etna was active in 1928, the railway line between Messina and Catania was blocked by lava streams 100 ft. wide, which wiped out one town and almost completely destroyed a village. In March 1932 the volcano, while covered with snow, gave spectacular signs of activity. Internal thunders of growing intensity came from the regions of the central and some of the subsidiary craters. Explosions occurred in the north-east crater which ejected puffs of sulphurous steam occasionally accompanied by cinders, with the result that the snow partially melted around the summit. A local winter sports competition was in progress, and it was held over ground which trembled beneath the snow. A strong wind frequently caused the mountain to be hidden by clouds of steam, and the snow-fields at the higher levels were from time to time lit up with the glow of the incandescent materials.

The volcano of Vesuvius (about 4,000 ft.) is the source of an unusual phenomenon the visitation of which is fortunately rare. It is the so-called hot rain. Small clouds of hot vapours escaping from the crater are carried here and there by the wind, and rain falling through these clouds when they are low reaches the ground in a hot state. This rain burns the eyes and makes the face smart, and has a destructive effect on vegetation. Crops, vineyards, undergrowth and tender shoots in the Vesuvian zone are scorched and ruined, and the whole region presents a desolate appearance. The stricken areas become tobacco-coloured after the hot shower. This phenomenon must be due to the vapours of hydrochloric acid which escape from the volcano in large quantities and, dissolving in the rain-water as it falls, pro-

duce dilute hydrochloric acid strong enough to have an irritant effect on the human skin and a scorching effect on vegetation.

Cotopaxi has been known to discharge shafts of fire to a height of 5,000 ft., and it sends huge stones flying to stupendous heights as if 'hurling defiance toward the vault of heaven'. At one of its eruptions it is reported to have hurled a 200-ton block of stone which fell 9 miles away! There is a smaller volcano in South America named Antuco, situated in Chile, which at an outbreak catapults stones to great distances, sometimes as much as 36 miles.

At many great outbursts, besides a constant shower of stones and scoriae or volcanic cinders, a huge column of fine particles rises from the craters to heights of upwards of a mile and is thereafter spread out by the winds like a sheet of cloud over a considerable area around. This cloud is sometimes so dense as to darken the skies and shut out sunshine from the whole area beneath for days together, so that continuous night reigns there during this period. The so-called sand erupted by many volcanoes is really lava in an extremely fine state of pulverization. It is a grey powder and bears a close resemblance to wood or coal ash. It is popularly called volcanic ash or sand. These minute particles, after hovering in the air for some time, finally settle down as fine dust.

The most recent eruptions which merit mention are those that took place in the Andes region in April 1932. On the 10th of that month the seaport of Valparaiso and other cities of Chile were rocked throughout the night and morning by subterranean disturbances, and earthquake shocks accompanied by underground rumblings lasting a whole night spread alarm in the volcanic zones of Chile and Argentina. The volcano of Descabezado (12,795 ft.) in Central Chile, long supposed to have been extinct, suddenly burst into fury and ejected clouds of ashes and showers of stones. A choking pall of volcanic ash covered an area as large as England. The air in some regions became poisonous owing to the fumes of sulphurous gas

mingling with it. Seven other volcanoes in the Andes similarly burst into activity within a few hours of this outbreak and discharged dense clouds of ashes. Valparaiso and Santiago were covered with the volcanic dust and white-hot cinders. Three days later two other volcanoes in Argentina became active.

The volcanoes concerned in this activity are of elevations ranging from 11,342 ft. for Las Yeguas to 21,550 ft. for Tupungato. Tupungato is the loftiest volcano which has erupted in recent decades. The distance between the farthest apart of these volcanoes is about 200 miles, and yet all of them were active at the same time. The explosions that accompanied the outbreaks were heard within a radius of 100 miles or more. A few airmen flew over the crater of Las Yeguas and heard loud detonations every half-minute and saw blocks of stone weighing several tons hurled to heights of over 200 ft. An American airman who flew over the volcano of Quizapu at an altitude of 14,000 ft., reported having seen a column of smoke which rose nearly a mile above the crater. For the three days during which the activity lasted, all the inhabited places in the volcanic region were in a state of semi-darkness on account of the continuous fall of ashes. It is estimated that by the end of this period upwards of 3,000 tons of material had fallen over Buenos Aires, more than 700 miles away from the nearest scene of activity. The farthest place reached by the volcanic ashes was Monte Video, a distance of about 850 miles from the nearest volcano in action.

It is the general view that, where a number of volcanoes lie in a group or at no great distances from one another, only one becomes active at a time while the others remain dormant. But these Andean outbursts show that vast underground forces are still at work affecting large areas. The solid land in the region of these Andean volcanoes, and in fact of all the active volcanoes in the world, must be a comparatively thin crust floating in a sea of magma just as an iceberg does in the ocean. The great

earthquakes which now and then rock various areas of the globe and the terrific volcanic eruptions that occur from time to time in different regions afford evidence that the subterranean forces which began shaping the earth hundreds of million years ago are still in operation. As a writer so forcefully puts it, 'for all the rigidity of what we call *terra firma*, mountains are still heaving, continents are still tilting, bed-rock is still trembling, while, beneath all, the primal magma is still welling.'

The region of the world which, relatively to its area, can boast of the largest number of volcanic peaks is the Dutch island of Java. We mention some of them which are still active, as their names are reminiscent of Hindu colonization of the island in the distant past. The highest of these peaks is Mount Sméru or Seméru. It stands 12,238 ft. above the sea. Seméru (समेरु) in Sanskrit means 'similar to Méru'. Among the other peaks are Guntur, Ardjunâ and Râwun. At its eruption in 1843 Guntur threw up ashes to an extent estimated at 30 million tons! There is a volcano in the neighbouring island of Sumatra named Indrapura, with an elevation of 11,800 ft. It is the highest peak in the island. It sends up dense clouds of vapour from time to time.

Merapi is another active volcano in Java. The beautiful temple of Mendut near the stupa of Bârâ Budur, referred to in Item 49 of the previous chapter, lay for a long time buried under a heap of ashes ejected by this volcano until it was unearthed in 1834. Volcanic activity in the island also exhibits itself in a decadent form, such as the mud-volcano of Grobogan in the Solo Valley about 30 miles east of Samarang. There is another volcano of this class in the near-by island of Madura.

Sumbawa, another island in the East Indian Archipelago and one of the Little Sunda group, contains 22 craters, of which Tamboro may be singled out for special notice. At a terrific eruption which took place in 1815 it lost nearly a third of its elevation, but it still retains a height of 9,042 ft. On the night of 5th April that year began a

series of frightful explosions which lasted five days. Vast quantities of ash were ejected which, rising into the air, enveloped a large area in a pall of darkness. The skies were now and again lit up by flashes of lightning. The ashes were carried to great distances, particularly towards the west. It was calculated that within a radius of 210 miles the average depth of this material was 2 feet. 'They floated in huge banks on the sea', says Professor Bonney, 'and buried a large amount of land.' The havoc caused by the eruption was enormous. 'Forests were destroyed, canals blocked, flocks and herds killed', and it took a heavy toll of human life too.

In the evening of 10th April the Raja of Sangir, an eye-witness, saw three columns of flame shoot up from near the top of the volcano and mingle in a confused manner above the crater. In a short time the whole mountain in the vicinity of Sangir looked like a huge body of liquid fire expanding in every direction.

The detonations which accompanied the outbreak were so loud that they were clearly heard at Jokjakarta in Java, 480 miles away. It was at first supposed that some enemy attack was in progress and even troops were rushed to repel it. To the north the reports of the explosions reached as far as the island of Ternate near Gillolo, a distance of 828 miles, and to the west they were heard at Mokko Mokko, a port near Bencoolen in Sumatra, 1,116 miles away! These startling data lead to no less staggering conclusions from the acoustic point of view. Seeing that the intensity of sound energy varies inversely as the square of the distance from the source, the intensity in this case must have been at the source more than a million times greater than at Mokko Mokko. And as the velocity of sound in air at ordinary temperature is about 1,050 ft. a second, the people of this place must have heard the explosions about an hour and a half after. Besides, as sound radiates or is propagated from its source in all directions and travels in continuous straight lines in an unobstructed medium *except in certain cases*, the detonations were possi-

bly heard in parts of Australia and at many other places within a mean radius of a thousand miles, so that the diameter of the circle covered by these sounds must have been very nearly a fourth of the diameter of the earth!

The reason for our remark that sound waves travel in straight lines in an unobstructed medium *except in certain cases* is that exceptions to this law of acoustics have been found in the case of sounds proceeding from gun-fire and similar explosions. Thus the explosion of a huge ammunition dump which occurred in Holland in January 1923 was recorded some 530 miles away, while no sound was heard at intermediate places 62 to 112 miles distant. The inference is that in this instance the sound waves travelled over part of the area in a curvilinear course, almost hyperbolic, creating a 'zone of silence' between their place of origin and the farthest point where they were recorded. The explanation of this peculiarity will be found in the Concluding Remarks under Chapter VIII.

But these records of the Tamboro outbreak, astounding as they are, pale into insignificance before those we have of the phenomenal eruption in 1883 of the island volcano of Krakatoa in the Sunda Strait between Sumatra and Java. The author owes much of his information about this outbreak to Sir Robert Ball's work, *The Earth's Beginning*.

For generations Krakatoa was quiescent and had almost ceased to be remembered as a volcano. In the spring of 1883 there were perceptible signs that it was at last awaking from its long slumber. First came earthquake shocks. Deep rumblings from the entrails of the earth gave warnings of approaching disturbances. And yet these symptoms of activity were regarded so lightly that some residents of Batavia organized a holiday excursion to the island. The more daring among them climbed up the sides of the volcano in the direction whence the sounds proceeded from the top. There they saw a huge column of steam issuing with awful noise from a deep fumarole about 90 ft. wide.

By the end of summer the noises from the crater had become considerably louder. At first they could

be heard 10 miles away and later at double that distance. Day by day the noises gathered intensity until they could be heard over a radius of 300 miles. Further signs were not wanting of the impending catastrophe. Each successive convulsion sent up clouds of fine volcanic ash high into the air, and a vast quantity of it was carried by the winds over great distances. The discharge of this material at last became so copious and frequent that the sky was obscured by the dense clouds it formed. The darkness grew deeper and deeper and sunshine being completely cut off, dawn and day were swallowed up in what seemed to be everlasting midnight! Land and sea within a radius of 100 miles and more were thus enshrouded in darkness. At Batavia, 100 miles away, lamp-light had to be resorted to in houses at noon time. Even at Bandung, situated at a distance of nearly 150 miles, and 2,300 ft. above the sea, the darkness of midnight reigned at midday. July came to a close and all the while the volcano was visibly developing its energy. As August advanced, the manifestations of activity increased in violence. There was panic over a vast extent of territory. People began to feel that a catastrophe of unparallelled magnitude was close at hand.

On the night of 26th August the skies, now darker than ever, were now and then illumined by lurid flashes from the crater. In Batavia the inhabitants passed a sleepless night. The houses trembled owing to violent earthquake shocks and the windows rattled as if heavy guns were being fired in the streets, but these were only premonitions of the supreme event.

The following day, 27th August 1883, saw the climax of the eruptions. At first there were two or three violent explosions. These were followed by an outburst so appalling that, in the words of Ball, it is destined to be remembered throughout the ages. The whole northern and lower portions of the volcano were blown up. Vast columns of stones and ashes were shot up into the air to stupendous heights. The seas around were terribly agitated. Waves lashed themselves into fury, and according to

reports, rose to a height of 50 feet and a few to even 100 feet! They invaded the shores of adjacent islands and played havoc over a large area. All the ships in the harbour were stranded. A vast quantity of floating pumice was carried for hundreds of miles on the surface of the ocean.

The din of the explosions beggars description. They were heard over an almost incredible area—in West Australia at a distance of 1,300 miles, at Bangkok in Siam 1,413 miles, in the Philippines about 1,450 miles, in Ceylon 2,058 miles, and in South Australia 2,250 miles away! But this is not all. Towards the west, south-west and due south the wide expanse of ocean presented a smooth, unimpeding sea of air for the sound waves to travel through. Thus the detonations were heard at Rodriguez, a small island north-east of Mauritius, and nearly 3,000 miles away from the scene of outbreak! Even at distances of over 2,000 miles they were heard like the reports of heavy guns! The farther passage of the sound waves in or beyond some of the countries was probably blocked by high mountain ranges. The intensity of the sounds must have been at the source nearly 9 million times greater than in distant Rodriguez, where, as was subsequently ascertained, they reached about 4 hours after the outburst, a period of travel quite in accordance with the velocity of sound. If we describe the circle of probable travel of these sounds, we shall find that its centre would shift to a point somewhere south-east of the volcano, and that its diameter would be at least 4,500 miles, considerably over one half of that of the earth!

A comparison of the range of audibility of a huge dynamite explosion with that attained by the Krakatoa detonations is not without interest. In September 1932 occurred a terrific dynamite explosion at Leeuwdoornstad in South Africa which was heard beyond Kokstad in the Cape Province, over 375 miles away! The thunders of Krakatoa, remarks Ball, were 'the mightiest noise that, so far as we can ascertain, has ever been heard on this globe.' It seemed as if Nature, in her wrath, fired a titanic gun

from the bowels of the earth, the shells which left its muzzle being the volcano itself which it sent up flying in fragments and smithereens to a maximum height computed at 17 miles or more! If so tremendous was the vertical range of this 'gun', still more amazing was the length of trajectory of some of its 'shells', for according to one report they fell in some cases 250 miles away! Of targets there were innumerable. Forests, plains and towns in the surrounding islands were subjected to fierce bombardment. There was huge loss of life. No fewer than 36,000 souls perished in the disaster. Practically the whole island, which before the eruption was about 18 square miles in area and had an elevation of 300 to 1,400 ft. above the sea, was turned into a submarine pit nearly 1,000 ft. deep. Several big forests in the neighbouring islands were wiped out, but the area occupied by them was increased by masses of the material erupted. New islets also appeared in the sea.

The eruptions caused atmospheric disturbance throughout the world. 'The atmosphere was struck such a blow', says Professor Daly, 'that the air waves were registered by barographs during three complete journeys round the globe.' The sea waves rolled on to immense distances from the centre of agitation. The long wave reached even Cape Horn, the southernmost point of South America, 7,818 nautical (or 9,000 English) miles away!

The Krakatoa outbursts produced certain other remarkable phenomena almost world-wide in their appearance. The finer particles of ash ejected by the volcano reached the upper layers of the atmosphere to a height calculated to have been nearly 20 miles and eventually spread over practically the entire globe. These particles made known their presence almost everywhere by the brilliant effects of sunrise and sunset glows. A reddish halo was observed round the sun. Glorious sunsets such as had never been witnessed before were now beheld in England and were ascertained to have been simultaneous with similar phenomena elsewhere in the world. A comparison of dates and

other particulars conclusively showed that these wonderful sights were due to the Krakatoa eruptions.

The volcano, though since under water, was active again in 1928 when it threw up lava and ashes, while columns of steam and water, 250 to 650 ft. high, were seen rising from the surface of the sea.

Gorgeous sunrise and sunset colours similar to those seen in 1883 were observed soon after the eruptions of Mont Pelée (West Indies) and Santa Maria (Guatemala) in 1902 and of Katmai (Alaska) in 1912, when a reddish halo was seen round the sun. In these cases too the ashes reached very high altitudes, and it is stated that the size of the particles could be calculated. In *Nature* of 23rd July 1932 appear reports of wonderful sunrise and sunset after-glows observed in South Africa in May, and it gives the substance of a report from Dr. E. Kidson, Director of the Meteorological Office at Wellington, of sunset after-glows seen in New Zealand from the second week of that month, which he describes as 'very beautiful, ranging in colour from pale pink to yellowish pink in the western sky, the appearance showing a certain amount of structure suggestive of thin high smoke.' His Department has received several reports of unusual manifestations of halo round the sun. Similar sunset glows since June are also reported from Australia, where they have appeared all over the Commonwealth. These magnificent phenomena are all attributed to the volcanic ashes which rose at the Andean eruptions of April. It is estimated that a quantity of this material amounting to the 1500th part of a cubic mile in volume, blown to heights of 10 to 50 miles, would suffice to diminish the intensity of the direct solar radiation at high sun by one-fifth, and Humphreys considers that this amount, if continued for an indefinite period, would be capable of producing an Ice Age.

The earth, it seems, is but a branch of that huge laboratory—the universe—where the master-hand of the Great Scientist is ceaselessly at work. But while these tremendous experiments unfold an endless variety of phenomena

for the enlightenment and edification of Humanity/ they often take, alas, a heavy toll of life! And as it is impossible to believe otherwise than that He is working with full foreknowledge of the results of His experiments, one can only sigh:—'Inscrutable sometimes are the purposes of Providence!'

CHAPTER V

The Giant Peaks of Asia

Th' increasing prospect tires our wand'ring eyes,
Hills peep o'er hills, and Alps on Alps arise!

—*Pope*

Aconcagua in South America is the loftiest peak in the world outside Asia with an elevation of 23,080 ft. It is difficult to ascertain exactly how many peaks there are in Asia exceeding this height. Noel gives an estimate of the total number of lofty peaks in the Himalayas. He states that there are 100 each 24,000 ft. high, 20 'giants' of 5,000 ft. and 6 'super-giants' of 27,000 ft. Capt. E. St. rnie, in his article on 'The First Ascent of Kâmet' in e fourth volume of *The Himalayan Journal*, points out that there are at least 36 known summits higher than Kâmet (25,447 ft.) within reach of India. Still, to Noel's total of 126, if we added Kângchenjunga, Godwin-Austen, Everest and the two Central Asian peaks, Tengri Khan and Tagharma, we would get the formidable grand total of 131 as the probable number of points in Asia which are higher than any to be found elsewhere on the globe! It must be borne in mind, however, that in a number of cases the same peak has two or more points rising 24,000 ft. or more and distinguished from one another by the suffix East, West etc.,

We have been able to trace 43 distinct peaks higher than the American giant. They are:—

1. **Kellas' Dark Peak Rock, Himalayas — (Observation of height taken from the Rongbuk Glacier, Tibet)** — **23,180 ft.**
2. **Pauhunri (Donkia), Himalayas—Lat. 27° 56′ 52″ N. Long. 88° 53′ 5″ E.** ... ... — **23,184 ft.**
3. **Dunagiri (Drônagiri), Himalayas** ... ... — **23,186 ft.**
4. **Badrinath Peak, Himalayas, in Garhwal—30° 44′ 16″ N., 79° 19′ 20″ E.** ... ... — **23,210 ft.**

5.	Cholpanglik, Karakoram Range—36° N. 81° E. ...	23,280 ft.
6.	Trishūl West, Himalayas, in Kumaon—30° 18′ 43″ N., 79° 49′ 7″ E.	23,400 ft.
7.	Gaurishankar, Himalayas, on the northern frontier of Nepal—28° N. 87° E.	23,440 ft.
8.	Tengri Khan in the Sary-Yassi Mountains, Central Asia	23,450 ft.
9.	Sankôsi, Himalayas, northern frontier of Nepal—27° 58′ 13″ N., 86° 28′ 32″ E.	23,570 ft.
10.	Golden Throne, Karakoram—36° N. 77° E.	23,600 ft.
11.	Dayābang, Himalayas, northern frontier of Nepal—28° 15′ 17″ N., 85° 33′ 35″ E.	23,762 ft.
12.	Mutsiputra, Himalayas, northern frontier of Nepal ...	24,000 ft.
13.	Aling Gangri, Himalayas, in the Khorsum Province of Tibet—33° N. 82° E.	24,000 ft.
14.	Kabru, Himalayas, in Sikkim—27° 36′ 26″ N., 88° 9′ 15″ E.	24,015 ft.
15.	Chamlang East, Himalayas, northern frontier of Nepal—27° 46′ 27″ N., 87° 1′ 21″ E.	24,020 ft.
16.	Chomolhari ('The Lily-white Mother of Snow'), Himalayas, northern frontier of Bhutan, but in Tibetan territory—29° 49′ 37″ N., 89° 18′ 43″ E.	24,100 ft.
	N. B.—It is one of the sacred Tibetan mountains venerated by Lamas and pilgrims. There are hermit dwellers in its cliffs.	
17.	Akn (Aku?), Himalayas, northern frontier of Nepal—28° 23′ 25″ N., 85° 10′ 12″ E.	24,313 ft.
18.	Jongsong La, Sikkim Himalayas	24,340 ft.
19.	Kulhakangri, Himalayas, northern frontier of Bhutan—28° N. 91° E.	24,740 ft.
20.	Bride Peak, Karakoram	24,764 ft.
21.	Jannu, Himalayas, between Sikkim and Nepal—27° 40′ 52″ N., 88° 5′ 13″ E.	25,304 ft.
22.	Tagharma, in the Pāmir region, believed to be a part of the Belut Tagh Range, which connects the Tien Shan Range with the Hindu Kush—39° N. 76° E.	25,360 ft.
	N. B.—A Ukrainean expedition is reported to have climbed to the summit of this peak in 1931.	
23.	Nimo-Nāmling, Himalayas, south-west of Lake Mānasarôvar, Tibet—31° N. 81° E.	25,360 ft.
24	Gurla Mandhata, Himalayas, south-east of Mānasarôvar—31° N. 82° E.	25,365 ft.

25.	Tirach Mir (observation of height taken from Gilgit and Chitral)	25,400 ft.
26.	Nameha (Namcha ?) Batwa, Himalayas—29° N. 95° E.	25,445 ft.
27.	Kāmet, Himalayas, in Kumaon — 30° 55′ 13″ N., 79° 38′ 4″ E.	25,447 ft.

N. B.—Almost all the books which we have consulted give the height of this peak as 25,431 ft., but the figure we have given here is taken from the cabled report of the conquest of the peak by Smythe and other members of his party. ... ...

28.	Nārāyani, Himalayas, northern frontier of Nepal—28° 45′ 39″ N., 83° 25′ 52″ E.	25,456 ft.
29.	Rakapushi, Karakoram—37° N. 75° E.	25,500 ft.
30.	Nandā Dévi or Jawāhir, Himalayas, in Kumaon—30° 22′ 31″ N., 80° 0′ 50″ E.	25,661 ft.

N. B.—This peak, says Mr. Hugh Ruttledge, 'imposes upon her votaries an admission test as yet beyond their skill and endurance; a 70-mile barrier ring, on which stand 12 measured peaks over 21,000 ft. high, and which has no depression lower than 17,000 ft.; except in the west where the Rishiganga river, rising at the foot of Nandā Dévi and draining an area of some 250 square miles of ice and snow, has carved for itself what must be one of the most terrific gorges in the world. . . . .

The most indefatigable explorer of this region has been Dr. T. G. Longstaff who was responsible for six of the nine recorded attempts to reach the mountain. In 1907 Dr. Longstaff and General Bruce achieved the only crossing of the barrier wall which has ever been made; from the north, by the difficult Bagini Pass (20,100 ft.).'

31.	Masherbrum, Karakoram—36° N. 77° E.	25,676 ft.
32.	Barathor, Himalayas, northern frontier of Nepal—28° 32′ N., 84° 9′ 52″ E.	26,069 ft.
33.	Gosain Thān, Himalayas, northern frontier of Nepal—28° 21′ 3″ N., 85° 49′ 21″ E.	26,305 ft.
34.	Gusharbrum, Karakoram—36° N. 77° E.	26,483 ft.
35.	Morahiadi, Himalayas, northern frontier of Nepal—28° 35′ 38″ N., 83° 51′ 46″ E.	26,522 ft.
36.	Nangā Parbat, Himalayas, in Kashmir—36° N. 75° E.	26,629 ft.

37.	Yāsaa, Himalayas, northern frontier of Nepal—28° 32′ 55″ N., 84° 36′ 9″ E.	26,680 ft.
38.	Dhaulāgiri ('White Mountain') Himalayas, northern frontier of Nepal—29° N. 84° E.	26,795 ft.
39.	Sibsur, Himalayas, northern frontier of Nepal—27° 53′ 18″ N., 87° 7′ 54″ E....	27,799 ft.
40.	Peak XIII or Makalu, Himalayas	27,800 ft.
41.	Kāngchenjunga, Himalayas, in Sikkim—28° N. 89° E. ...	28,146 ft.
42.	Dapsang or K 2 or Godwin-Austen, Karakoram— 36° N. 77° E.	28,283 ft.
43.	Everest, northern frontier of Nepal— 28° N. 87° E. ...	29,145 ft.

The Himalayas are not a single continuous range, but a series of colossal natural ramparts, 100 to 150 miles thick and with the Karakoram nearly 2,000 miles long, strengthened by massive skyscraper bastions rising one alongside the other, towering one behind the other, in almost endless succession, and clad in eternal snow. What Byron writes about the great Alpine peak can with greater force apply to all these Asian giants:—

' Mont Blanc is the monarch of mountains;
They crown'd him long ago
On a throne of rocks, in a robe of clouds,
With a diadem of snow.'

Superb as the Alps are, the Himalayas have to-day a still stronger fascination for the foreign tourist. Nooks and valleys, gay with flowers of lovely hues and bright with silvery cascades or pearly streams, are embosomed in their grim and titanic elevations. With their sublime grandeur and infinite variety of detail and natural beauty rivalled nowhere else in the world, the Himalayas have for ages past furnished many a theme for the poet's song.

The Himalayas are held in great veneration by a very considerable section of the Hindus. In Védic times when the elements were worshipped, when the more awe-inspiring of natural phenomena had a divine significance for the Aryans, the majestic range of the Himalayas—a name which means ' the abode of snow '—was regarded as the home of the god of storms, the mother of rivers and the

haunt of fierce wild beasts. Such a conception led to the belief that this mighty mountain range was the abode of all the gods. From time immemorial great souls have sought its enchanting retreats with their entrancing solitudes to enjoy the bliss of nearer communion with the Divine Spirit. Every peak, every river, lake, spring and cascade is hallowed by a legend of gods, sages and saints, and as such, makes a strong appeal to the religious sense of the vast bulk of Hindus. Throughout the great epic of Mahābhārata, Himāchala (another name for the Himalayas) is looked upon as holy ground, the beloved home of the gods. 'He who thinks of Himāchala, though he may not behold him,' says the sage Dattātriya to King Dhanvantari of Kāshi (Benares) in the Mānasa Khanda of the Skanda Purāṇa, 'is greater than he who performs all worship in Kāshi. As the dew is dried up by the morning sun, so are the sins of mankind by the sight of Himāchala. Nay, all beings that, at the hour of death, think of him and his snows obtain forgiveness for their sins.' 'In a hundred ages of the gods, O King,' winds up the sage, 'I could not tell thee of the glories of Himāchala.'

CHAPTER VI

The Earth's Atmosphere : The Upper Troposphere

Though the Troposphere is a continuous layer of the Earth's Atmosphere, we have divided it into two parts or sub-layers mainly for the sake of convenience. Mt. Everest, as we know, forms the highest limit of the earth. We may consider—with due respect to the World's Powers and to International Air Law—that altitudes exceeding that of Everest not being existent on the earth are the exclusive empire of the airman and of the 'space voyager' of the future! We have therefore thought fit to deal with the rest of the Troposphere in a separate chapter, after bidding an affectionate farewell to Mother Earth.

For a long time we have been on the wings of imagination. It is about three o'clock in the afternoon. We have just left behind our last foothold on the earth after a hardy climb, vertically measured, of nearly 9 miles, for that is the height from the level of the Hawaiian 'Inferno' to the 'Roof' of the Earth. Looking through our spy-glass, we notice a lammergeyer and a couple of those omnipresent birds of India, the crows—sole representatives of earthly life visible from this great height—as they fly below the summit of Everest. A veil of clouds blots out the Nepalese side from our view. The tablelands of Tibet we see as scattered islands swimming in a thin filmy sea, indeed an ocean, of clouds, for our horizon radius is over 200 miles.* On, on we fly over this mighty range, sweeping in quick succession past Gaurishankar, Dhaulāgiri, Gurla Mandhata, Mānasarōvar, Rākshas Tal, Kailās, Nandā Dévi, Kāmet, the Badrinath, Kédarnath and Karakoram peaks, feasting

* For ready calculation, with fair accuracy, of an observer's horizon radius at a few miles' height above the earth's surface, the formula $\sqrt{\frac{3}{2}h}$, where *h* is his height in *feet* above the ground, may be used.

our eyes upon the majestic grandeur of the snow-capped heights stretched at our feet, though revealed to our view as a long archipelago of islets glistening from between thin sheets of mist. Far in the west, as we gaze towards the horizon, we see the setting sun with a sky aflame with crimson and orange, while the higher slopes of the mountains below us, as we look back again and again, reflect its rays with a rapidly changing kaleidoscopic effect as the sun sinks lower and lower.

On, on we fly in the latitude of the Karakoram, at something like 450 miles an hour, keeping all the while a thousand feet above the elevation of Everest, until at the end of about fifteen hours we find overselves over a certain place in the United States of America. Night is yet in its infancy here. Suddenly a large cylindrical object darts past with deafening detonations, belching forth tongues of flame, and after reaching about a thousand feet above us, rushes back towards the earth, for it evidently came from the earth itself. What remarkable object could this be? We shall know anon.

(1)	Height at which the Ionization of the Atmosphere has been found to be nearly 6 times that at the earth's surface	9 km. = a little over $5\frac{1}{2}$ miles

Note

The minute system called the atom consists of a central positively charged nucleus and a negatively charged particle or particles termed electrons revolving round it. Certain elements like the metals radium, uranium and thorium have the property of emitting powerful rays capable of passing through opaque matter, and the branch of physics known as *radio-activity* deals with the properties of these rays and the processes taking place within the atom which give rise to this emission. Materials which eject rays of this character are called *radio-active* substances. All radio-active materials emit three distinct types of rays designated by the Greek letters *Alpha, Beta* and *Gamma*. The first two are streams of particles and the last are waves. The Alpha particles are the posi-

tively charged nuclei of helium atoms, and they carry with them the bulk of the energy that emanates from radio-active substances. They are hurled at a velocity computed at 12,000 miles a second and can deliver a blow with such force as to shatter the very heart of some atoms. Their tracks can be rendered visible by suddenly expanding a mass of saturated air and immediately illuminating it. The Alpha rays can be deflected by an electric or magnetic field. Although they can pass through even very thin glass, these rays are of considerably less penetrating power than the Beta or Gamma rays. The Beta rays are streams of electrons, the negatively charged particles of the atom. They are shot out at terrific velocities, the highest speed approaching that of light which is 186,285 miles a second, but like the Alpha rays they too can be deflected by an electric or magnetic field. The Gamma rays are a type of Röntgen or X-rays of very high frequency, and they usually accompany the emission of Beta rays. They are the most penetrating of all the three rays and will penetrate through metal walls and other objects which stop the passage of Alpha and Beta rays. The shortest of Gamma rays will penetrate 8 inches of lead, while the extent of penetration of X-rays is only half an inch of the same metal. The Gamma rays travel at the full velocity of light.

The electrified atoms or oppositely charged electric particles into which gases break up by the action of electric discharge or certain penetrating rays or by solar agencies are called *ions*. Ionization is the phenomenon of such separation. The ionization of the atmosphere near the earth's surface is partly due to the presence of traces of radio-active material in the soil under the lower layers of the atmosphere. The vast majority of physicists consider that the influence of the sun, if anything, in this phenomenon is very small. By ascents in balloons and aeroplanes equipped with instruments, scientists have discovered that there is a decrease in ionization with height up to an altitude of about 3,300 ft. but above this level it gradually increases. This is attributed to radiations coming from outside the earth. Both physicists and astronomers are interested in the mystery of these rays which are extraordinarily penetrating, more penetrating than even the Gamma rays from radio-active atoms, and have been found to pass through great thicknesses of matter. The individual rays bombard the earth with

such energy that only a wall of lead 18 ft. thick can intercept them. They are, however, not only invisible but comparatively small in quantity. They are consequently very difficult to observe and cannot be photographed like the invisible ultra-violet rays or X-rays. They are detected by their ionizing action on gases.

As a result of measurements taken in recent years many scientists have declared that these radiations are equally strong both day and night and have consequently come to the conclusion that they do not proceed from the sun but come from some other source. It has, besides, been found that they come to the earth from *all* directions. Sir James Jeans, the distinguished physicist-mathematician-astronomer, has put forward the theory that they are due to the annihilation of matter on the confines of space. These rays are hence called *cosmic* rays. Dr. E. N. da Costa Andrade, Quain Professor of Physics at the University of London, while stating that many arguments can be found in support of Jeans's theory, adds that the origin of these rays is still in doubt. He remarks that their very nature, whether they are waves or particles, is at present uncertain and points out that investigations are still being energetically pursued both in Europe and America to ascertain definitely their source, composition and properties and are likely to yield valuable results bearing upon the structure and distribution of matter in space.

One important property of these rays, by studying which scientists hope to gain an insight into their nature, is that they diminish in intensity as they pass through matter. Experiments in this direction have been made by Dr. Kohlhörster in Switzerland and by Dr. Robert A. Millikan, the most eminent American investigator of these rays, and his co-workers in America, by lowering recording electrometers to different depths in snow-fed lakes. In Lake Constance, Switzerland, the penetrating rays have been detected at a depth of 236 metres (nearly 775 ft.). Millikan and his collaborators have also shown that the rays are not homogeneous but of varying degrees of absorptivity. The estimated wave-length of the most penetrating of cosmic rays—assuming that they are waves and not particles—is $0{\cdot}63 \times 10^{-13}$ centimetre, a value so small that something like 40 trillion of these waves are required to make up a length of one inch! According to Millikan's calculations, the longest

cosmic rays are 18 times longer than the shortest of them. The shortest ray has been found to penetrate 500 ft. into the earth's crust. It is owing to their exceedingly short wave-lengths that cosmic rays, X-rays and Gamma rays are able to penetrate opaque objects. The range of wave-lengths included in the region commonly designated as X-rays extends from 10^{-6} to 10^{-9} cm. (about four-millionths to four-billionths of an inch), and that of Gamma rays from 10^{-9} to 10^{-10} centimetre (four-billionths to 4/10-billionths of an inch).

Two American physicists, Dr. L. M. Mott-Smith and Mr. G. L. Locher of the Rice Institute in Texas, report to the American Physical Society that, in experiments they carried out to make visible the path of these rays, they appeared as a train of tiny droplets of water in a strong light—a rapidly moving train of thin, bullet-like particles. Simultaneously with the formation of each bullet-track the experimenters observed a signal in a delicate electroscopic instrument called the Geiger-Müller counter, employed to detect the arrival of the rays from the depths of space. They conclude that only a swift-moving particle like the electron could give such indications. It is contended by advocates of the wave theory of the cosmic rays that their behaviour as corpuscles is due, not to the track of the rays but to secondary electrons expelled from the atoms of air gases encountered by the rays in their path. Kohlhörster is among those who think that these rays are high-speed electrons, a view not acceptable to most physicists, for electrons entering the earth's magnetic field from outer space would spiral round the Poles, whereas according to them the rays are as powerful at the Equator as anywhere else. Millikan maintains that the rays are fast-moving non-material waves like the Gamma rays of radio-active atoms. He has recently reiterated this view, reinforcing it by conclusions based on the discovery made by his collaborator, Dr. Carl D. Anderson, that the cosmic rays can disrupt the nucleus of an atom. A third suggestion has been put forward that they may be photons or bullets of light—the individual splashes of radiant energy which constitute a beam of light.

Dr. W. F. G. Swann, Director of the Laboratory of the Barton Research Foundation at the Franklin Institute, Philadelphia, has

built and installed at Swarthmore (Pennsylvania) a 'cosmic-ray telescope' with which he hopes to find out whether the radiations come with uniform or varying intensity from different directions in space. This device is a highly sensitive electroscope consisting of two steel spheres filled with nitrogen gas, with a lead cylinder which acts as a shield between them. The conductivity of the nitrogen increases with the radiation from the cosmic rays and promotes the passage of more electricity to the recording instruments. But if the radiations proceed from one direction and one sphere is directed there, it will intercept a portion of them from the other sphere behind it, and this difference can be measured.

It is considered that the higher mountain peaks in the north-west of India present a unique position for the observation of cosmic rays and atmospheric radiations, owing to the clearness of the air in these regions. Dr. Arthur H. Compton, Professor of Physics at the University of Chicago, some years ago came to India specially to make observations of cosmic radiation from some of these peaks. He has recently constructed a steel 'ionization chamber' for measurement of the intensity of the cosmic rays. A short time ago he took measurements with this apparatus on the top of Mount Evans (about 13,000 ft.) near Denver, Colorado. According to his findings, these rays vary in intensity with altitude as well as with the time of day, *i.e.*, with the intensity of sunlight. He found an average difference of 1 per cent between the twelve daylight and the twelve night hours. The conclusion is reached that this variation, unless due to some unknown atmospheric phenomenon, suggests that the portion of space in the neighbourhood of the sun emits cosmic rays more copiously than the more remote regions. He also measured their intensity at different latitudes and found that there was a difference of 24 per cent in the strength of the rays at the Equator and at the Magnetic Pole. He hopes he will shortly be able to prove the electron or particle theory of these rays. Compton's new announcement only deepens the mystery of the cosmic rays. It is not too much to say that the phenomenon of cosmic radiation has so far baffled the best scientific minds of the day and that some time must elapse before there can be an authoritative and more widely agreed theory as to their origin and nature.

In India too the subject of cosmic radiation has been recently receiving attention at the hands of physicists. An expedition to the mountain heights of Kashmir under the leadership of Mr. J. M. Benade, Professor of Physics at the Forman Christian College, Lahore, shortly following the summer of 1932, made observations at various summits ranging from 13,000 to 19,500 ft. in elevation. After taking readings with the Compton apparatus at a level of 19,500 ft. where the party spent two days and nights, Professor Benade made further observations by means of his own electrometer, an apparatus with a thin-walled ionization chamber and light shields of various metals. He announces that he has obtained interesting and perhaps new data with this apparatus. The maximum height from which observations were made probably represents the highest land elevation from which cosmic radiation has yet been studied. Additional observations were made at suitable places on the return journey, the most interesting being those made 386 feet underground in a tunnel of the Mandi Hydro-Electric scheme. The members spent a number of hours in this tunnel where they were effectually screened from cosmic rays, so that they were able to obtain data which they hope will be helpful in checking the formulae used in calculating the results of all their observations.

(2) Average Altitude of Cirrus Clouds ... About 30,000 ft.

Note.—A new method of computing the height of clouds has been lately devised. We may reproduce in this connection an extract from *Popular Mechanics Magazine* of June 1931 :—

'To enable Airports to measure accurately the height of clouds above the ground, a powerful searchlight has been made which utilizes a comparatively small bulb. The light projects a very narrow beam with such intensity that a newspaper can be read 5 miles away by its rays. Although the lamp used is only 5 or 6 times the size of the ordinary bulb used in the home, efficiency of the reflector system compensates for this. The principal glass reflector is in the form of a parabolic mirror, which throughout its surface is focussed directly on the lamp filament. The light, containing a 420-watt bulb, produces 1,840,000 candle-power.'

The projection of light was recently demonstrated at Cleveland, Ohio, U.S.A., by an airport and airway lighting engineer of the Westinghouse Electric and Manufacturing Company. The light was projected from a

searchlight throwing a narrow beam over Lake Erie. The beam over its course spread only 12 ft. a mile. The narrow beam makes possible the determination of the height of cloud banks more accurately than by previous methods.

(3) World's Altitude Record for a Sounding Rocket } 31,152 ft.

Note—This particular rocket was constructed by Dr. Darwin O. Lyon, an American rocket expert, and was fired on 29th January 1929. It was over 8 ft. long and carried in its tip apparatus for registering atmospheric pressure and temperature besides a contrivance for obtaining a sample of upper air. At the height it attained, the density of the air was found to be 0·28 of that at sea level, its temperature –18°F. (–28°C.) and composition almost exactly the same as that found at sea level. Lyon's next rocket, a large object nearly 12 ft. long and weighing, minus fuel, 132 lbs., was constructed on the principle of sections, one rocket being placed within another. In this method as soon as one section finished its work, its empty shell dropped off and automatically ignited the charges contained in the section above, so that, each time a section went off, the machine became lighter and propelled itself with the velocity imparted to it by the section that had just dropped off. In the foremost section were placed recording instruments and a contrivance for securing a sample of the air at the highest point which the rocket would reach. In front of these instruments and folded into the tip was a parachute to which the case containing registering apparatus was attached. Immediately below this case was a 7-inch gyroscope intended to keep the rocket in the right course. This elaborate machine, however, met with a disastrous end on 2nd February 1931 in the course of its trial on a somewhat steep slope. The rocket was travelling in a ski-carriage, but after going a few yards began to slip sideways, when one of the mechanics endeavoured to correct its direction with a pole. The pressure thus exerted on the axis of the gyroscope loosened it from its bearings, and it fell downwards through the rocket with the result that the whole charge in it exploded at once, killing one man and seriously injuring two others. Lyon is however zealously pursuing his dangerous experiments and, with the combined efforts of himself and other rocket experts, the time

may come when rockets carrying automatic instruments become a valuable auxiliary in the conduct of meteorological observations.

It may be of interest to know what velocity the wind is capable of developing at such a height. A few years ago an aviator in America, attempting an altitude record near Dayton, Ohio, found the wind at a height of about 6 miles from the ground blowing West to East at about 300 miles an hour! He experienced no abnormal winds at the time he left the ground.

In England, for the last 14 years the Meteorological Department has been under the administrative control of the Air Ministry, an arrangement which has done much to bring about intimate co-operation between the airman and the meteorologist. Furnished with the necessary instruments, airmen-meteorologists make aeroplane ascents and take observations, but as the method is expensive, the work is confined to a height of about 20,000 ft. Yet the results were found to be so valuable that this method was quickly adopted by meteorological services in several other countries also. But as the aeroplane is driven by a powerful engine which causes the entire craft to vibrate and strongly heats the air in the immediate vicinity of the structure, it has been found necessary to design special apparatus for use on aeroplanes. In England the instruments used are of the type in which readings have to be taken on a scale or dial. Ascents are made twice a day. The pilot wears electrically heated clothing and carries oxygen apparatus. A writing pad is strapped on his knee to facilitate the recording of observations. On the dashboard in front of him is an accurate aneroid barometer, and within easy reach is a pair of thermometers projecting from a metal case connected to a broad duralumin pipe, the other end of which is away out on the wing facing forward. When the aeroplane is in flight, a stream of air will rush through the pipe and over the bulbs of the thermometers. With its bulb wrapped in muslin, one of these instruments, which is capable of being depressed into a Dewar flask containing water, will give the wet bulb temperature, from which the humidity of the air can be ascertained. This device makes possible adequate moistening of the wet bulb even when the temperature of the air is considerably below freezing-point. The pilot watches his barometer closely and reads his thermometers at certain definite values of the pressure which of course falls steadily with

height. At the same time he makes notes of the cloud forms and visibility. On alighting at the aerodrome, he codes his readings for transmission to the Meteorological Office of the Air Ministry.

In other countries, especially Germany, Belgium and America, automatic recording instruments are preferred, as they relieve the pilot of a considerable amount of work.

(4)	World's Altitude Record for Observation Kite	9·74 km. = 6 m. 154 yds. (*Humphreys*)

Note.—At the great Lindenburg Meteorological Observatory near Berlin, observation kites and hydrogen-filled rubber balloons, with instruments attached to obtain the atmospheric pressure, temperature and humidity at various levels, are sent aloft by an electrical windlass. The readings are recorded on paper cylinders attached to the instruments. The kites and balloons are at last hauled down by the windlass. The weather reports are then broadcast to the European air-ports. The observatory has a radio tower 295 ft. high.

(5)	World's Altitude Record for Seaplane or Flying Boat	33,455 ft.

Note.—This height was reached in a seaplane flight by the American Navy flier, Lieut. C. C. Champion, some years ago. In 1929 Lieut. Apollo Soucek, a pilot of the United States Naval Air Force, attained a higher altitude in a land aeroplane fitted with pontoons.

(6)	World's Altitude Record for Balloon carrying two men in open basket	35,424 ft.

Note.—This record was set up by the German aeronauts, Süring and Berson, as long ago as 31st July 1901. The temperature registered at this height was -42° C. (-43·6° F.).

It may be of interest to note that a Burman drawing master of Tavoy named U. Kyaw Yin, who has never seen a balloon in his life, has constructed a crude one of his own design. It is buoyed up by smoke produced by burning rags of gunny bags soaked in crude oil. Kyaw Yin performed some acrobatic feats and hung upside down from his balloon at a height of over 1,000 feet at a trial ascent which he made in 1929 in the presence of the Deputy Commissioner and other officials at Tavoy. The balloon is 60 feet in height and 30 feet in diameter.

(7)	World's Altitude Record for Aeroplane carrying two men	37,854 ft. = 7 m. 1 f. 78 yds.

Note.—This record was set up by Capt. St. Clair Streett and Capt. A. W. Stevens of the U. S. Army Air Corps at Dayton, Ohio, in 1929.

(8) Highest Altitude from which Aerial Photographs have been taken } 37,854 ft.= 7 m. 1 f. 78 yds.

Note.—The photographs were taken by Stevens at the flight just referred to.

Aerial photography has latterly made great strides in countries more advanced in aviation. We have come across a notable instance of a very distant object lying beyond the farthest range of vision having been photographed from the air. Photographs recently taken by an American Army officer from an aeroplane flying at a height of 17,000 ft. revealed a mountain over 200 miles away. The significance of this fact will be better realized when we point out that the horizon distance which one would command at this height is about 160 miles, while the mountain lay miles farther.

(9) 'Halt! Beware!' warns the mysterious Voice again.—

'*Roof*' of the Troposphere, or End of the Storm-bearing Area, the first or lower layer of the Earth's Atmosphere } 38,280 ft.= 7 m. 2 f.

Note.—The air pressure here would be about 1/5th of that at sea level.

CHAPTER VII

The Earth's Atmosphere: The Tropopause

As stated at the beginning of Chapter III, the Tropopause is the boundary region between the Troposphere and the Stratosphere. Clouds are not usually found in this region except in tropical latitudes.

(1) World's first penetration of the Tropopause in Aeroplane Solo Flights, as 'officially' recognized } 41,790 ft.— 7 m. 7 f. 70 yds.

Note.—The German airman, Willy Neuenhofer, reached this height on 28th May 1929. The temperature recorded at the top of the flight was about –55° C. (–67° F.). There are a few earlier instances where airmen have been reported to have flown past the 'Roof' of the Troposphere, but their records were either not referred to or were disallowed by the Fédération Internationale Aéronautique. For an aviation or aeronautical record to acquire the status of a word-record, it is necessary that it should be confirmed by this body or by an Aero Club or similar other institution which is a member of it. Records so ratified are known as 'official', and those either not referred for recognition or achieved without strict compliance with the rules of the Fédération, are called 'non-official'. Neuenhofer's record was duly confirmed by this body.

Some Pertinent Queries:

(i) Is an airman at this altitude safe everywhere from anti-aircraft artillery attack?

(ii) Is there any artificial light in the world that can spot an aeroplane at such a height in clear weather on a dark night and hold it in its beam?

(2) Vertical Height to which Shells can be fired by America's Anti-aircraft Artillery Gun } 42,000 ft.

This is a mobile gun of 3-inch calibre, weighing over 8 tons and firing 15-lb. shells. It can fire 25 shots a minute, can be swung round through 360° and has a horizontal range of 60,000 ft. It has an average elevation range of 75° which, to our knowledge, is the highest angle of elevation at which an artillery gun has been so far designed to fire. At an emergency the gun can be rushed from place to place at a speed of 40 miles an hour. It has been adopted as the standard equipment by the Anti-Aircraft Section of the United States Ordnance Department, which now owns a number of batteries of these guns. It is claimed that this new gun represents the high-water mark in the field of artillery modernization.

It may be mentioned that, at a vertical fire, a shell does not travel throughout in a straight line. Owing to the action of gravity, it gradually leaves its straight course and begins to travel in a parabolic curve. The greatest height above ground reached in the course of its flight is called the 'vertical height' attained by it, which, in the case of this new American gun, is stated to be 42,000 ft. The actual distance in a straight line, covered by its shell at a vertical fire, represents the hypotenuse of a right-angled triangle having for one of its other sides the line of perpendicular height reached by the shell, and will be found by trigonometrical calculation to be 43,481 ft.

France has designed an anti-aircraft gun which can fire shells to a vertical height of 12 km. (39,370 ft. = 7 m. 3 f. 115 yds.), and initial tests carried out at Toulon early in 1932 were found satisfactory.

An anti-aircraft gun has to face a special problem in hitting an object, as its target is moving in three dimensions. A curved trajectory has to be eliminated as far as possible. These weapons are therefore designed to have a flat trajectory, or rather one with the least possible curvature, besides a high muzzle velocity.

3 and 4-inch guns are now controlled by an anti-aircraft director, a highly delicate multiple instrument consisting of a number of co-ordinated instruments and extremely complex in operation. One part of it is a range-finder, which enables the gunner to ascertain with accuracy the altitude of an aeroplane in flight. This height recorded, another part of the instrument locates the target accu-

rately, calculates its ground speed and also foretells its location at the precise moment the shell is timed to burst on attaining the calculated height at a pre-determined point in the air.

Besides the batteries of 3-inch land guns, America's naval arm includes anti-aircraft naval guns of the most modern type. Her latest 32,000-ton Super-electric Dreadnaughts, capable of attaining a maximum speed of 20½ knots, are armed with powerful guns, operated electrically, which can be elevated to a high angle and can fire 5-inch shells at hostile aeroplanes or balloons flying over the ocean, up to a height of 4 miles straight up. These mammoth battleships are also fitted with aeroplane catapults, which would enable fast and powerful bombing aircraft to leave the vessels at a moment's notice and give battle to enemy aeroplanes flying high above.

Besides special artillery guns, other powerful anti-aircraft weapons—or rather devices—have been manufactured in recent years, *viz.*, searchlights of extraordinary candle-power.

A searchlight is an electric arc lamp furnished with special contrivances to throw the light in any required direction. The discovery of the electric arc is due to the great scientist, Sir Humphrey Davy, the inventor of the safety-lamp for coal-miners. In the searchlight, the light of the arc is focussed by a reflector and projected as a bundle of parallel rays of high intensity, the illuminating power increasing with the size of the projector.

America has a battery of anti-aircraft searchlights of 1 billion and 1,400 million candle-power respectively, which are operated by electricity. The former can throw a beam to a distance of 35 miles and it is said that, 10 miles away from the source of any of its beams, a newspaper can be read by its light, and that near the source its blue-white ray has the same intensity as the noon-day sun! Besides these, America is installing a still more powerful searchlight offered by the New York inventor, Sperry. It is of 2 billion candle-power, and is meant for use in peace time as an aerial beacon for aviators during night-flights. Its light at the source is expected to be so dazzling as to exceed the intensity of midday sunlight by over 10 per cent. It will revolve at the top of a tower which projects 125 ft. above the roof of a skyscraper standing on a lake-front in Chicago. It is claimed that this searchlight is capable of throwing

on clear nights a beam to a distance of 500 miles, which will sweep in a huge circle touching one-fourth of the total number of States in the Union.

France has a gigantic searchlight of 3½ billion candle-power. Its beams of light flash messages in code, to guide aviators at night. It is controlled by radio. The radio control, a wireless apparatus, is miles away from the lamp and operates a shutter so that the code messages are transmitted in flashes of light. The lamp can be elevated up to an angle of 90° for operations against hostile aircraft.

A British firm of electrical engineers has constructed two mammoth searchlights, each of 3½ billion candle-power, to the order of a small Baltic State, to be used for coastal as well as aerial defence. In order to increase the utility of the projector to the utmost, special arrangements are provided for effecting control of its movements, either locally or from a distance. The distant control is operated electrically, and if necessary, the operator can be stationed miles away. The light has an elevation angle of 90°. These searchlights are of massive size, the apparatus being about 14 ft. in height and the projector approximately 7 ft. in diameter. Each of them can throw a beam to a distance of 300 miles. The spread of the beam, 2 miles from the mirror, is 150 ft. When in action against an enemy naval squadron, its tremendous range will be reduced by the earth's curvature to less than 20 miles. In operating against invading aircraft, its gigantic rays will sweep the skies with a powerful blinding glare, until the raiders are caught in the deadly beams at whatever height they may be flying.

Powerful searchlights can direct anti-aircraft guns to their target at night, so that the two different weapons can be brought into action simultaneously. When, however, dense clouds hang over the searchlight station, the usefulness of both these weapons will clearly be limited.

(3) Highest Altitude at which Instrumental Music has been heard through a Radio Receiving Set — 42,000 ft.

Note.—A jazz orchestra playing on the earth was listened to at this great height by the balloonist mentioned in Item 4 below, the music coming in clear and loud on his radio.

(4) World's Unofficial Altitude Record for Balloon Solo Flights } 42,470 ft. = 8 m. 76 yds.

Note

The balloonist was the American flier, Captain Hawthorne Gray, but his record was disallowed by the Fédération Internationale Aéronautique, as owing to his balloon falling faster and faster he had to make a parachute leap while 8,000 ft. above ground. For an altitude record to be officially recognized, the whole flight should be achieved without resort to the parachute. Gray made a second attempt to re-establish and, if possible, to beat his own record, but with fatal results. On the second occasion it was claimed on his behalf that he had reached the same altitude as on the first, but this record too was disallowed, as he—or rather his body—was not found to be in 'possession' of his instruments. These two ascents were made in 1927. At this altitude, the temperature registered at the first flight was -55^0 C. (-67^0 F.), and the air was found to be ·5 times thinner than at sea level.

Experiences at High Altitudes

Away from his natural surroundings on earth, man is liable to four kinds of sickness: sea-sickness while at sea; air-sickness while flying at ordinary altitudes; mountain-sickness at elevations of 10,000 to 20,000 ft. on mountain heights; and 'altitude-sickness' while scaling lofty peaks after 20,000 ft. or while flying at an altitude exceeding this.

Two American airmen, on reaching an unofficial altitude of 39,000 ft., saw just below them the following interesting phenomenon, says *Popular Mechanics Magazine* of May 1929:—

> 'Ice caves, apparently hanging in festoons in the air, and decked in all the brilliant colours of the rainbow, as the tiny ice particles broke up the sunlight, which presented an awe-inspiring sight.'

This strange phenomenon is called a 'Mirage of the Upper Air'. One of the airmen dived down the aeroplane into these ice caves, removed a glove and stuck his hand out of the fuselage, with the result that it was stung in hundreds of places by the minute ice particles. The other airman exposed one side of his face to the

blast and got a bad ice blister. At the height reached by the airmen, the sky is said to have looked deep blue-black 'except for a brilliant ball of fire where the sun rode'.

In the thin and rarefied air at such an altitude, the sky appears magnificent in the depth of its colouring owing to the absence of dust particles. The balloonist, Gray, describes its colour as 'a deep, almost cobalt, blue'.

In the course of his remarkable ascent, Gray found it necessary to lighten his balloon. Among other things he dropped, attached to a special parachute, a steel cylinder of oxygen weighing 25 lbs. In the rarefied air and owing to being weakened by the inhalation of oxygen for some time, he found the cylinder so heavy as to seem to weigh at least 150 lbs. as he struggled to lift it over the rim of the balloon-basket.

As, during his descent, the balloon was falling faster and faster, Gray similarly dropped (attached to parachutes) some more oxygen cylinders to lighten the balloon still further. He found that his balloon was falling much faster than the cylinders were descending, so that he was struck with wonder at the apparent sight of the cylinders soaring upward instead of falling as his balloon dashed past. Added to this singular illusion was the spectacle, familiar to airmen, of the earth appearing to rise higher and higher to meet him instead of *his* going down and down!

We may quote here as an instance of Kālidāsa's vivid and penetrating imagination, a few lines from Monier Williams' translation of the poet's immortal drama, *Shākuntala*. In Act VII, Verse 8, King Dushyanta, as he descends from heaven in Indra's car, and approaches the earth, describes his experience to the charioteer, Mātali :—

'How wonderful is the appearance of the earth as we rapidly descend!
Stupendous prospect! Yonder lofty hills
Do suddenly uprear their towering heads
Amid the plain, while from beneath their crests
The ground receding sinks; the trees, whose stems
Seemed lately hid within their leafy tresses,
Rise into elevation, and display
Their branching shoulders; yonder streams, whose waters,
Like silvery threads, but now were scarcely seen,
Grow into mighty rivers; lo! *the earth*
Seems upward hurled by some gigantic power.'

Sensations at Great Altitudes

(Nearly all the information that follows is taken from *Popular Science Monthly* of September 1927).

1. The extreme cold of high altitudes causes great physical discomfort.
2. The flier is burned by the sun's ultra-violet rays unless he coats his hands and face with grease.
3. Respiration becomes difficult as the lungs fail to function normally.
4. The beating of the heart at times becomes audible, the hands and lips become blue, the breath freezes, and the moisture in the ear-drums and eyes has been known to freeze, causing intense pain therein and temporary deafness and blindness.
5. The slightest exertion causes acute distress, and the face requires the exercise of a strong will to make and read observations.
6. If his oxygen gives out, it may mean disaster to the flier. 'The insidious thing about running out of oxygen is that there is no gasping for breath, no danger-signal to warn the pilot. The figures on his instrument dials gradually grow blurred, the mind is wandering.' He is overtaken by a terrible weariness, followed by unconsciousness, though there have been occasional instances where the airman has recovered consciousness in time to right his machine and make a safe landing.
7. There is the ever-present sense of danger of the electric apparatus, carried by the airman to keep himself warm, failing to act—which means death !
8. 'An awe-inspiring spectacle down below—the earth, lying at a tremendous depth, seems to be swimming in its ocean of clouds.'

Equipment and Outfit for Altitude Flights

The following particulars are drawn partly from *Popular Mechanics Magazine* of February 1928 and partly from *Aero Mechanics* of October 1929.

1. At his record balloon ascent in 1927 Capt. Gray wore over the heaviest of underwear two woollen shirts, a sweater and a winter uniform, and on top of all these, a flying suit, leather on the outside and reindeer-fawn skin on the inside, with two thicknesses of heavy woollen blanket-cloth between. His flying clothes alone weighed 57 lbs.
2. Special Goggles with double glasses for each eye-piece separated by one-inch air-space which was warmed by an electric heater to prevent the formation of frost on the glass pieces. Frost on the glass would completely obscure the airman's vision, and hence this precaution.
3. Leather Face-Helmet lined with fur.
4. Oxygen Mask—attached to the helmet.
5. Parachute Harness.
6. Canister strapped to the chest, containing electric oxygen heater.
7. Fur-lined Gloves kept warm by an electric heater.
8. Fleece-lined Leather Moccasins for the feet.

A veritable climbing apparatus !

(5) World's Altitude Record for Aeroplane Solo Flights } 43,978 ft. = 8 m. 2 f. 135 yds.

Note

This record was established in September 1932 by Capt. Cyril Uwins, a war-time pilot in the British Air Force and now chief test pilot to the Bristol Aeroplanes Company. His machine, a Vickers Vespa biplane, was five years old, and he used a 550 horse-power Bristol Pegasus engine. From the Bristol aerodrome he climbed steadily for over two hours, and he eventually landed in a ploughed field near Evesham. Narrating his experience, he said :—

'When I reached 40,000 ft., I was surprised to find flying conditions rather bumpy. At such heights the air is generally believed to be smooth. For nearly an hour I was flying in a kingdom of intense coldness, sitting in the open cockpit occupying myself with breathing from my oxygen supply. . . . . . . I intended to land at Filton, but in the heavy haze I lost my bearings . . . . Flying conditions were not good, and I was relying entirely on my oxygen supply above 20,000 ft. . . . The machine behaved perfectly.'

The temperature registered at the peak of the flight was -72° F. ($-57 \cdot 8^\circ$ C.). His record has been confirmed both by the Royal Aero Club and the Fédération Internationale Aéronautique. The previous record was held by Lieut. Apollo Soucek, a pilot in the United States Naval Air Force, who attained a height of 43,168 ft. in 1931.

The holder of the altitude record for the time being is sportingly styled in American aviation circles as the 'wearer of the icicle crown'. This title of course can only go to a flier who achieves the record in an open cockpit or balloon-basket, as an airman going up however high in a sealed chamber or car will not be exposed to the minute ice crystals of the upper atmosphere.

It is worthy of note that Soucek and Uwins are so far the only men who have taken a 'heavier-than-air' craft to a height beyond the range of the most powerful anti-aircraft gun of the day.

How fast would a man fall from a great height?

This sounds like a strange question, yet it has engaged the serious attention of experts in countries where parachutes for airmen are designed and constructed. We shall reduce our question to a specific problem of Dynamics, but put in a different form :—

> If a man fell from a height of 43,978 ft. above ground, how long would it take for his body to reach the earth ?

According to the well-known formula in Dynamics—*Space* $=$ $\frac{1}{2}$ *gravity* $\times$ *time*^{2}, it would take $52\frac{1}{4}$ seconds if we left out of account the resistance of the air. The initial speed of a falling body, *i.e.*, its speed for the first second, is 16·1 ft. The velocity increases in each successive second owing to the action of gravity. Experiments have shown that this rate of increase is 32·2 ft. per second, so that the speed of the body during the 52nd second of its fall, assuming that it has been falling from a great height, will be 1,658 ft.

In this connection, the results of careful experiments made by the United States Navy's Bureau of Aeronautics make interesting reading. Two articles appeared in *Popular Science Monthly* of September 1928 and May 1929 respectively. In the course of night-

experiments carried out preparatory to the designing of parachutes capable of standing the strain which they have to bear, dummies of the shape and average size and weight of a man, carrying flares by which their fall could be observed from the ground, were dropped from an aeroplane flying high. A camera set up on the ground, which had a shutter that winked at one-second intervals, took photographs of the dummies in the course of their fall. Their speed could thus be measured by the length of the streak of light on the picture after each second. The tests showed that the dummies, after falling about 1,600 ft., did not continue their fall any faster. The explanation given is that air resistance prevents further increase in speed after this point is reached. Speaking in general terms, a body after falling about 1,600 ft. would reach its maximum speed or terminal velocity of 100 to 120 miles an hour—only about one half of the speed calculated with the resistance of air left out of account. The writer of the second article goes so far as to remark that the pilot of this aeroplane has helped to revise the law of gravity so far as its practical application is concerned!

Mr. Charles Dixon, an ex-observer in the British Royal Air Force, in his book, *Parachutes for Airmen*, says that the highest speed which a man attains during a fall never exceeds 250 miles an hour, a rate which, by the way 'would at the worst bring water to the eyes if goggles are not worn, while it would not affect the breathing.' The terminal velocity of a falling body will therefore, according to Dixon, be reached after a fall of about 2,320 ft. covered in 12 seconds.

(6) 'Back, back! Death waits ahead!' yells a stentorian Voice.—

Point at which the air pressure becomes so low that, as altitude fliers describe it, the muscles of the body can no longer function to operate the lungs, so that a man who took in a breath of oxygen could not exert enough muscular action to expel it and would die	In the neighbourhood of 45,000 ft.

Note

In *Popular Mechanics Magazine* of June 1928 appears the following explanation by a medical authority of what would happen to a man exposed to the conditions at such an altitude:—

'Somewhere between 40,000 and 50,000 ft. is undoubtedly the absolute limit for man, even when supplied with oxygen, under ordinary circumstances. Somewhere between these limits, the exact point varying according to the temperature of the air, the barometric pressure is reduced to 100 mm. of mercury, in other words, the air will support the weight of only that small fraction of an inch of mercury. . . . . . From this atmospheric pressure must be deducted 47 mm. of water-vapour, which accumulates in the inspired air before it reaches the lungs. This leaves 53 mm. possible available oxygen pressure if pure oxygen could be breathed. If a man was breathing absolutely pure oxygen, this would be sufficient to sustain life, but under no present available method of taking oxygen, either through a tube or a mask, does the oxygen remain undiluted. It does become diluted by the nitrogen in the air. Also, under the effects of the diminishing pressure, nitrogen is given off by the blood, as in caisson disease, which attacks workers digging deep foundations. This nitrogen from the blood still further dilutes the air. If the oxygen pressure could be kept up to about 53 mm., it still would be necessary to maintain the carbon-dioxide pressure.'

We shall now give a clearer idea, from the view-point of mathematical physics alone, of the extent of reduction in the air pressure at an altitude like 45,000 ft. The barometer here will read about 100 mm. or 4 inches, against 760 mm. or 29·92 inches at sea level. The weight of a cubic foot of air at a given level is ascertained by the formula:

$$\text{Weight (in lbs.)} = \frac{1{\cdot}3253 \times \text{Barometer Reading in inches}}{459{\cdot}6 + \text{Temperature of Air in Fahr.}}$$

Suppose the air temperature at a given moment, say, at the seaport of Bombay, is 78° F. The weight of a cubic foot of air here will be ·07375 lb., and the weight of all the air in a room 12 ft. 8 in. long, 10 ft. broad and 12 ft. high, will be *1 cwt.*, a result, incidentally, which shows that, in spite of the familiar phrase 'light as air', this fluid has appreciable weight. If, however, the air in this room were entirely replaced by hydrogen, the lightest of all elements and gases, the total weight of the gas in the room would be only *7 lbs.*, or again, if helium gas were substituted, its total weight would amount to *16·8 lbs.* Let us now suppose that an aeroplane having a cabin of the above dimensions with a couple of open windows, is taken up to an altitude of 45,000 ft. The temperature there will be about –70° F. The whole of the air in this cabin will then weigh only

$$\frac{1.3253 \times 4}{459.6 - 70} \times \frac{28}{5} \times 10 \times 12 = 20.7 \text{ lbs.}$$

In other words, the air at the high level would press upon the body of a person in the cabin with a weight less than a fifth of what it was at the starting-place, and this pressure would be only 1·23 times greater than if the cabin contained helium instead of air. The relation between altitude and atmospheric pressure, as will be noticed from the above formula, depends to a considerable extent on the temperature of the air.

How does an aeroplane behave at its 'ceiling', that is, the top limit of its flight? It wallows with its wings and propeller, slipping through the highly rarefied air, unable to 'take hold'. Even a balloon, as large as the one used by Gray which was buoyed up by 80,000 c. ft. of hydrogen, behaves little better. Before it can reach the 'ceiling', where the outside air is very considerably thinner, it refuses to carry the pilot's weight any higher. The American Army Experimental Laboratory had therefore designed and built an air-tight metal balloon car for Gray, but he never used it, as he considered it to be more dangerous than exposure in an open basket. He pointed out that, while the air-tight car would keep him in air at ground-level atmospheric pressure during a flight, it would make it impossible for him to leave the balloon for a parachute jump in an emergency. The sudden translation from ground-level pressure to the highly rarefied air of the upper regions would be almost instantly fatal, the body literally blowing up from the pressure within it!

But dare-devil pilgrims like us who are bent upon going 'higher still and higher', will take all risks, change here into such a car, furnish with large glass windows its sides as well as floor and ceiling, and proceed, despite the menacing Voice from the Sky! Let us hope there will be no more need for warnings from this source lest some members of the party should be disheartened!

(7) 'Halt, halt! Would ye break your heads?' thundered the Voice.—

'*Roof*' of the Tropopause, or End of the Boundary Region between the two layers of the Earth's Atmosphere } 45,000 ft. = 8 m. 4 f. 40 yds.

Note.—The temperature here will be, as stated above, about -70° F. (-57° C.).

That a voice from the sky in these days need not be quite an offspring of the imagination is shown by the report that a device is soon to be used in suppressing tribal risings in Iraq and the Indian Frontier by the monster Vickers-Napier bombing aeroplanes of the Royal Air Force, which will be equipped with microphones, amplifiers and loud-speakers. The apparatus is said to be capable of amplifying the human voice more than a million times! The crew, instead of straight away dropping bombs on the villages, will first utter into the microphones warnings and threats which will emerge from the loud-speakers as an awe-inspiring, booming voice from the sky! In these operations it is proposed to use this novel device from the midst of clouds at a height of a few thousand feet.

In civil aviation, too, a voice from the sky is not unfamiliar in countries which are highly advanced in aviation. Powerful loud-speakers carried in aeroplanes are being used for what is known as 'sky-shouting'— the shouting of advertisements. In England prohibition of this practice is now recommended by the House of Commons Select Committee on 'Sky-writing'— the projection of lantern slides on to the sky.

CHAPTER VIII

The Earth's Atmosphere: The Stratosphere

This is the second or upper layer of the Earth's Atmosphere. Unlike the Troposphere it is free from storms and fogs. The information available about this region and the rest of the Atmosphere above is incomplete, and in some cases the results of observations as announced are far from conclusive. In fact, these upper regions of the air are being continuously explored and, as a result, scientists from time to time bring forward new theories modifying and occasionally even overthrowing previous ones. Sometimes conflicting theories are put forward by scientists differing among themselves. These are factors which make it difficult for any but scientists of high attainments to accept one theory in preference to another. We must consequently deal with these regions of the Atmosphere with caution.

One may wonder how it is that, while scientists have explored regions far away in the profundities of space—the Solar, Stellar and Nebular Systems—to a fairly wide extent, such a comparatively low region as the Upper Atmosphere has not yet completely yielded to research. Modern instruments like the spectroscope, the telescope, the micrometer, the spectrohelioscope, the interferometer, the radiometer and the thermocouple have enabled physicists and astronomers to wrest many valuable secrets out of these systems. Much of our knowledge of the Upper Atmosphere is derived from observations taken by means of 'sounding balloons' equipped with self-registering instruments, but these contrivances have a 'ceiling' very far below the top of the whole Atmosphere. Consequently our knowledge of the constitution and physical properties of its upper regions is incomplete. Such knowledge as has been gained is the

result of observations from the earth of shooting stars, aurorae etc. There are certain phenomena like cosmic radiation, for instance, which cannot be thoroughly studied with the help of the automatic recording instruments available to-day.

(1)	World's Altitude Record for automatic transmission of Wireless Signals	Over 16 km. or 52,493 ft.

Note.—During the cruise of the famous German Airship *Graf Zeppelin* in the Arctic regions in 1931, four miniature balloons of a special type invented by the Russian scientist, Professor P. A. Moltschanoff of the Aerophysical Observatory at Leningrad, and equipped with automatic meteorological instruments and small radio-transmitters, were released from a special compartment built into the airship, and these transmitters signalled temperature and humidity values obtained from different altitudes. Three of the balloons attained heights of over 16 km., and it was found that at about 80° N. lat. the temperature in the Stratosphere at the highest altitude reached was -50° C. (-58° F.). The air pressure at such an altitude would be about 1/10th of that at sea level.

(2)	Highest Tropical Cirrus Clouds ...	10 miles
(3)	World's Altitude Record for Balloon carrying two men in a sealed gondola	16,700 metres = 54,790 ft. or 10 m. 3 f. 3 yds.

Note

The aeronauts were Professor Auguste Piccard, the famous Swiss physicist and meteorologist, and his assistant Dr. Max Cosyns, who reached the above mentioned altitude in the Professor's second ascent to the Stratosphere on 18th August 1932 from Zurich in Switzerland.

In his first ascent made in May 1931 from Augsburg (Bavaria), Piccard was accompanied by Dr. Kipfer. The balloon measured 184 feet from top to bottom. Taking a 10 hours' supply of oxygen for a voyage estimated to last 7 hours, the two men hermetically sealed themselves in an aluminium gondola which was fitted to the balloon. The interior was maintained at ground-level atmospheric pressure. The gondola was designed apparently in much the same way as the American Army Experimental Laboratory did its metal

balloon car for the use of Gray who, as mentioned in the previous chapter, never availed himself of it, feeling that it was more dangerous than exposure in an open basket. Piccard carried three parachutes, two for releasing meteorological instruments and the third to be fixed to the gondola to bring its occupants back to earth. The object of the ascent was to take meteorological observations of the upper air and to carry out an exploration of cosmic rays. The aeronauts had an adventurous landing. Early in the morning following their ascent an innkeeper of the village of Gurgl, who saw in the clear weather a balloon lying on the Oetzel Alps in the Austrian Tyrol, hastened to the spot with a rescue party and found the occupants alive. After attaining a height of nearly 10 km., they had come down and alighted smoothly the previous night on the Gurgl Glacier. The exact altitude reached by them, as subsequently announced officially by the Swiss Aeronautical Federation, was 15,781 metres (51,774 ft.). At this point the pressure was found to be 1/10th of that at sea level. While one side of the balloon was kept very warm throughout, the other was exposed to the cold of the Stratosphere. The lowest temperature recorded was -60^{0} C. (-76^{0} F.), while within the gondola the thermometer showed 41^{0} C. above zero (106^{0} F.) as the black paint of the former absorbed considerable heat from the sun.

Professor A. M. Low, the British scientist, made some important remarks in connection with this ascent. He thought it would be possible to reach even double the height, though a colossal balloon would be required for the purpose. Although for scientific purposes a great deal could be achieved between the heights of 10 and 20 miles by the use of self-registering instruments without endangering human life, it would not be possible to record automatically some of the observations which Piccard wanted to make, as the necessary instruments had yet to be revolved. Spectroscopic and other observations taken on the earth were affected by the smoke and fog of the lower atmosphere. Piccard considers that observations from the Stratosphere may be of the highest value to astronomy if the oscillations of the balloon in which the astronomer goes up can be prevented.

The names of Piccard and Kipfer will go down in the history of aerial navigation as the first men to reach and sail in the Stratosphere.

In his second ascent Piccard beat his own record. The gondola used this time was provided with a porthole through which either of the occupants could put out his head up to altitudes where it was not dangerous to do so. They carried sufficient oxygen to last 36 hours, an ample food supply, chiefly fruits, two parachutes, an array of delicate meteorological instruments, a wireless equipment and 1,500 lbs. of powdered lead as ballast for it. 40,000 people assembled at the Dubendorf aerodrome near Zurich at sunrise to witness this remarkable ascent. An aeroplane took off shortly before the balloon in order to film it, but was soon outdistanced by the balloon which rose rapidly and disappeared from the view. Wireless messages from the Professor kept the expectant world informed of his progress in the upper regions, and near midday he reported that he had crossed the Upper Engadine valley in Switzerland at an altitude of 16,000 metres (54,134 ft.), that all was well, that it was very cold up there and that he would soon descend so as to avoid the risk of coming down in the Adriatic Sea. The balloon eventually landed on a wheat-field near Desenzano on Lake Garda in Italy after a further climb of some 700 metres. The aeronauts narrowly escaped death when the balloon landed. The Italian peasants of the place, apparently misunderstanding the Professor's instructions given in French, instead of lashing the mooring ropes to trees, relinquished them with the result that the balloon at once shot up to a height of 150 feet and then crashed down, and the envelope was damaged. Only the wicker helmets worn by the occupants saved their lives. They nearly fainted on landing owing to the sudden change from the high altitude cold to the sweltering heat of the Italian summer, but soon recovered. The temperature registered at the highest point reached was -36^0 C. ($-32{\cdot}8^0$ F.). The aeronauts had remained 12 hours in the air and travelled a distance of about 100 miles.

Piccard expressed great satisfaction with the flight. The atmospheric visibility was perfect throughout. Even at the top of their flight they could see the earth clearly. Minor details of course were blurred in the landscape, but they could distinctly make out mountains, lakes and forests, and they could see both the Adriatic and the Mediterranean. The Professor expects that the scientific results obtained will prove to be of great value. He confirmed the disco-

very already made by other physicists that cosmic rays increase in intensity with altitude after a few thousand feet, and stated that finally he could feel them beating on the surface of the balloon and the gondola like rain! Piccard contemplates making his next ascent from Hudson Bay in Canada, near the Magnetic Pole (which lies several degrees lower than the geographical Pole), with the object of studying the influence of cosmic rays. He expressed his belief that cosmic radiation was directly related to cancer.

In his second venture Piccard flew in *two* Stratospheres, but it can be claimed that in his first ascent he sailed in one more! Lest any extravagant idea of his achievements should be formed from this somewhat cryptic remark, we hasten to explain its meaning. The second flight covered two territories in the skies, the 'Swiss Stratosphere' and the 'Italian Stratosphere', while the first covered three—the 'German Stratosphere', the 'Austrian Stratosphere' and the 'Italian Stratosphere'—strange, unfamiliar terms perhaps! But the custodians of International Air Law, for whom we have the highest respect, have drawn maps parcelling out aerial regions amongst the various powers—Great, Middling and Small—from the base of the Troposphere up to possibly the farthest limits, if at all there are any, of the *earth's gravitational pull* (as understood in physics and not in any sense of attraction or hunger for land or territory) !

In Germany the Junkers Aeroplane Company has completed the construction of a Stratosphere monoplane designed by Herr Asmus Hansen, an inventor and one of the most skilled and experienced altitude fliers in Europe. It is said that it will shoot through the rarefied upper air like a rocket and fly at a height of 10 miles or more, where the absence of clouds, shifting winds, storms, rain, lightning, fog, snow or sleet and the crystal clearness of the air would enable an aeroplane to fly in considerably greater safety and the feeble resistance of the air would facilitate flights at tremendous speeds. At such a height the air is about ten times less dense than at the surface of the earth, and consequently both the driving power required and atmospheric resistance are as many times less, and in spite of the intense cold no ice is formed and deposited on the aeroplane owing to the insignificant quantity of water-vapour present in the upper air. The wings and propellers of this machine are so

constructed that they are readily adjustable. The pilot can lengthen them when necessary and thus increase the 'plane's 'grip' and maintain its buoyancy in the rarefied air. It has a wing span of 92 feet and is equipped with a Junkers Diesel engine of a new design burning crude oil. The motor is provided with powerful air compressors known as superchargers, to make up for the rarefaction of the air necessary for carburation. The diminution in driving power will thus be made good. The 'plane weighs nlearly 4 tons. Its metal cabin, which will be electrically heated and lighted, is an absolutely air-tight chamber with double walls, with 5-inch space between, and double windows with panes capable of withstanding a temperature of -73^{0} C. (-100^{0}F.) outside and plus $15{\cdot}5^{0}$ C. (60^{0}F.) inside. Straight panes had been found to break under pressure even after they had stood the temperature tests, and for this reason glass of a new and special manufacture is used. The chamber will be equipped with filters to absorb the moisture of the occupants' breath. The interior will be kept at normal air pressure, and the occupants will use oxygen throughout. The 'plane will carry a fully equipped laboratory so that the scientists on board may carry out tests of the air and other scientific investigations in the upper atmosphere. It will carry also a short-wave transmitter and receiver, which will enable the pilot to communicate with the earth at all times. The machine is described as the world's most marvellous aeroplane, and it is expected to fly at a speed of not less than 400 miles an hour in the Stratosphere.

France has not been less active. Mons. Henri Farman, head of a famous French Aircraft firm, has just completed a similar but smaller monoplane to be used for a like purpose. It made a short trial flight recently. Its cabin is an air-tight duralumin cylinder, shaped like a capsule, 80 inches in length and 40 inches in diameter. It has small portholes like the one in Piccard's gondola, through which the pilot can put out his head up to heights where it is not unsafe to do so. After a certain height they will be hermetically closed. The Farman 'Plane, unlike the Junkers machine, is without windows. French experts point out that, if the double windows of the German machine should both break during its flight in the Stratosphere, it would mean instantaneous death to the occupants. The Farman machine, it is stated, may be able to develop the tremendous

speed of 500 miles an hour in the thin region of the Stratosphere. In this connection the 1932 October number of *Popular Science Monthly* makes the following interesting remarks :—

> 'At the latitude of Paris, a plane going 500 miles an hour could circle the world in a single day. Because this is true, the first pilot to head westward from the French capital at 500 miles an hour literally will race with the sun. Because he will be going fast enough to circle the earth in 24 hours, he will remain in a fixed position in relation to the sun while the earth is spinning beneath him. If the Farman plane heads west at that pace, its pilot, Lucien Coupet, will be the first man since Joshua to see the sun stand still in the sky !'

Another machine, a huge monoplane with wings of variable area designed by an expert French engineer, is nearing completion. Its inventor expects that it will be able to climb 10 miles in 40 minutes.

It is reported that the preliminary tests of Germany's pioneer Stratosphere 'Plane—or 'Stratoplane' to use an abbreviated term adopted by some writers—which has a theoretical speed of between 300 and 400 miles an hour after reaching the rarefied air 6 miles up, have been satisfactory. Its first flight is to be from Berlin to New York and is expected to be made in 12 hours.

America is reported to be engaged in building a similar machine. Great Britain does not want to lag behind in this new bid for supremacy of the air, and according to report, plans are afoot for the construction of a monster Stratoplane able to carry a large number of passengers.

If these Stratoplanes prove successful, as is highly probable, they will enable the world to add materially to its present stock of knowledge of the upper atmosphere.

(4) Height at which a Sounding Balloon is reported to have registered a temperature of –133° F. (–92° C.) over the equator — 11 miles (*Pop. Sc. Monthly*, Sep. 1927)

Note.—Sounding balloons filled with hydrogen are sent up at important weather stations to ascertain atmospheric conditions. They carry self-recording thermometers and barometers to great heights and ultimately burst. A small parachute then brings the instruments gently back to earth and they are thereafter examined. In some countries as in India the instruments are tied inside a protected bamboo frame or cage and are usually sent up in the balloon without a parachute. The resistance of the air to the downward movement of the deflated balloon acts to some extent as a

brake, but for special purposes a parachute is sometimes used. Sounding balloons often drift scores of miles away, in which case recovery of the instruments carried by them presents great difficulty. A balloon released by the Indian Meteorological Department at Poona in August 1929, after bursting, descended at Girjutapalli, a village 3 miles from the town of Vikarabad in the Gulburga District of the Nizam's Dominions, over 250 miles away as the crow flies.

(5) Height up to which the Constituents of the Air, with the exception of water-vapour, are well mixed by winds and by diffusion — 12½ miles (*Encycl. Br.*, *1929*)

Note

The normal components of dry air and the volume percentage in which they usually occur in it, according to Humphreys' *Physics of the Air*, as also the approximate atomic weights of the elements present, are :–

Constituent	Volume percentage in dry air	Atomic Weight
Nitrogen	78·03	14
Oxygen	20·94	16
Argon	0·9423	40
Carbonic Acid Gas	0·03	44 (molecular weight)
Hydrogen	0·01	1
Neon	0·0018	20
Helium	0·0005	4
Krypton	0·0001	83
Ozone	0·00006	48 (molecular weight)
Xenon	0·000009	130

Water-vapour is present in the air generally to the extent of 1·2 per cent which may increase to over four times as much, but it is almost absent in extremely cold weather. Ozone is one and a half times as dense as oxygen, and carbonic acid gas about the same number of times heavier than air. The composition of air varies, however, and the percentages of distribution of the constituents do not strictly depend on their atomic weights or densities. On the earth's land surface, the composition is influenced by vegetation, latitude and proximity to the sea. Altitude too brings about changes, but the variations are not very great at elevations where breathing is yet possible without the aid of oxygen.

Dr. J. R. Partington, Professor of Chemistry at the University of London, states that the atmosphere tends to settle down into layers according to the heaviness of its constituent gases, so that, above a height of 12½ miles, the composition of the air would rapidly change through the heavier particles tending to descend to the bottom and the lighter particles to rise to the top. In the upper atmosphere, therefore, there would be considerably more hydrogen and helium than in the lower regions.

The abovenamed ten gases along with water-vapour form the natural permanent constituents of pure air, but the atmosphere is always vitiated by the presence of what are called 'impurities' such as bacteria and other micro-organisms, gases given off from factories and by the decay of organic matter or those generated by electrical phenomena like thunder-storms.

(6) Greatest Height reached by a Gun Projectile } Over 18 miles

Note.—During the Great War the Germans bombarded Paris from a distance of 76 miles with long-range guns of special make firing 265-lb. shells. This type of giant gun is since known as the 'Big Bertha'. According to Mons. Esnault-Pelterie, the famous French scientist, these shells had an initial velocity of 1,400 metres (4,593 ft.) a second, and at a certain moment reached a height of over 18 miles. The long range was attained by using this high velocity and firing at an elevation of 55°, so that the shells swiftly passed through the lower layer of dense air and reached the rarefied region of the atmosphere. The *Encycl. Br.* (*1929*) states, however, that the greatest height of the trajectory was 24 miles.

(7) Indian Altitude Record for a Sounding Balloon } 30 km. = 18·75 miles

Note.—This height was reached by a balloon sent up at Agra by the Meteorological Department in March 1931.

Two important records of the temperatures registered at great altitudes by sounding balloons sent up by the Department at its head-quarters at Poona are before us. One sent up on 14th May 1930 attained an altitude of 17·2 km. (10·75 miles) and another sent up on 19th August 1930 of 26·6 km. (16·625 miles). The temperature registered at the latter height was −53·8° C. (−64·8° F.) and at the former height as low as −90° C. (−130° F.).

(8) Indian Altitude Record for a Pilot Balloon } 32 km. = 20 miles

Note.—This height was reached by a pilot balloon sent up at Ahmedabad by the Meteorological Department in March 1931. Pilot balloons carry no

instruments and are observed as they rise, through special theodolites, for the determination of wind directions and velocities at various heights in the free atmosphere.

Both sounding and pilot balloons are comparatively small objects and are, of course, unmanned.

(9)	World's Altitude Record for a Sounding Balloon	35·08 km. = 21 m. 7 f. 88 yds. (*Humphreys*)

Note.—According to *Popular Science Monthly* of September 1927, which gives the height in round figures (22 miles), this height was reached by a sounding balloon sent up in Germany. The temperature registered at this height was -52° C. (-62° F.) — (*Negretti & Zambra*). In Millikan & Gale's *Practical Physics* is given the previous record of 21·8 miles, this height having been attained by a little balloon sent up on 7th December 1911 at Pavia in Italy.

(10)	World's Altitude Record for a man-made device—a Pilot Balloon	39 km. = 24 m. 3 f. (*Humphreys*)
(11)	Lowest Height at which Fireballs or Glowing Meteors disappear in their fall	20-30 miles

Note

The Sanskrit name for a Meteor or Shooting Star is *Ulkā* or *Ulkushi*.

Meteors are very small astronomical bodies travelling in countless swarms through space. Many of them are smaller than a grain of sand and few bigger than a playing marble. Their orbits are so numerous that they intersect the earth's orbit almost everywhere, so that they are continually encountered by the earth in the course of its revolution round the sun. They reveal themselves to our observation as aerolites, fireballs or shooting stars. Long before a meteor flashes into view, it has been hurtling across space at a velocity much greater than its rate of speed after becoming visible. This is due to the fact that its path up to its first point of visibility lies through space infinitely more void than that in the exhausted receiver of an air-pump. But as the meteor strikes the atmosphere, its velocity begins to diminish. At last, owing to its friction with the rarefied air of the upper atmosphere, its energy of motion is converted into the energy of heat, and it rapidly becomes red-hot and bursts into view. But in a few

fleeting seconds, rarely more than two, it perishes in a streak of brilliance, being finally dissipated in vapour or impalpable dust.

The smaller shooting stars are consumed before they can penetrate very far. The larger masses, however, which appear, not like flying stars, but as brilliant fireballs lighting up the whole landscape, often descend much lower, sometimes as low as 20 to 30 miles, before their speed sufficiently diminishes to make them cease to glow. The well-known meteor showers belong to the Solar System and move round the sun in elliptical orbits which intersect the earth's orbit (which is also elliptical) at or near a definite point.

When meteors fall in daytime, they are seen as white clouds. The number of meteors that enter the atmosphere per hour can be computed more accurately than the duration of their visibility.

From a long series of observations, one astronomer estimates that the average velocity of the fireballs ranges from 42 to 46 miles a second. As such a speed is far above the limit for bodies belonging to the Solar System, he concludes that they start from the depths of space and that they descend in a hyperbolic course. It is therefore probable, he thinks, that they abound in interstellar space. As they rush across the atmosphere, they produce a roaring noise and leave a luminous cloud in their trail. Some of the larger ones as they descend look even larger than the moon. Either owing to the sudden compression of the air in its path or to the accumulating pressure or to both causes, most of them ultimately break up into smaller masses with a loud explosion usually followed by unearthly sounds.

The astronomical study of meteors began only in 1833. On 13th November of that year, a meteoric shower of extraordinary brilliance was witnessed from the eastern parts of North America. It was estimated that upwards of 200,000 shooting stars were observed at one place between midnight and dawn. Many of them were very bright and left persistent trains of luminous matter. The most magnificent example of fireballs was the 'Meteoric Procession' of 9th February 1913. This remarkable cluster was first seen over Canada and, after travelling about 5,700 miles across the sky, was last observed over the Atlantic, but still pursuing a south-easterly course. It consisted of four or five groups of 40 to 60 members each. Along the observed portion of their path, their height was only

about 35 miles. At many places in Canada their passage was accompanied by a thunderous roar which even shook houses at eight stations. It is on record that a similar phenomenon was witnessed at Cairo as far back as 1029 A. D.

While the smaller meteors or shooting stars are burnt up in the upper air, the larger bodies sometimes fall to the earth, but considerably reduced in size. These are called meteorites. They vary greatly in size. The smallest discovered have been as small as a grape seed, while the heaviest and one of the largest, the Cape York meteorite, weighs 37½ tons. It was found in Greenland in 1897 and is now lying in the American Museum of Natural History. The total number of meteorites discovered runs to thousands. A big meteorite, if it falls on land, may cause devastation. On 30th June 1908 an extraordinary event occurred in the wilds of Siberia. At about 7 in the morning a huge meteor of dazzling brilliance was seen in the sky by thousands of people in the southern part of the Province of Yenesei. At what place it fell remained unknown for nearly twenty years, until in 1927 a scientific expedition traced it in the heart of a dense forest. At the spot where the meteorite struck, there is now an area many miles in diameter where the ground is 'torn and furrowed as though by a gigantic harrow and pitted by large funnel-shaped cavities, like shell holes.' All around this area, for hundreds of square miles, lie dead trees in countless numbers and the remains of vegetation scorched in a manner which shows that the scorching was not due to forest fire. The sudden compression of the air under the huge falling mass must have generated intense heat and sent out a furious blast that uprooted and shattered the trees. At the nearest settelment, 40 miles away, people were scorched by the heat and houses were damaged. A storehouse was destroyed by fire and several tools in it were found in a molten state. A herd of 1,500 domesticated reindeer was wiped out of existence. Railwaymen working 400 miles away from the site of the fall felt the hot-air wave and heard a roaring noise. At the Irkutsk Observatory, 800 miles away, the wave was registered by a barograph and the shocks of the falling body were recorded by a seismograph. In London, over 3,500 miles away, six microbarographs recorded a mysterious rush of air, which lasted 20 minutes, as if a terrific explosion had occurred. This is probably the largest meteorite which has

struck the earth in historic times, says Sir Richard Gregory, the famous scientist, 'and its weight must have been thousands of tons.'

Meteorites are covered with a very thin, slag-like crust of black, produced probably by the intense heat to which they are subjected in their rapid passage through the atmosphere. Those which are composed mostly of crystalline rock are called *meteoric stones* or *aerolites*. They contain small grains of nickel-iron embedded in softer material. Those composed almost entirely of nickel and iron are known as *meteoric irons or siderites*. There is an intermediate group, the *siderolite*, which contains rock material and nickel-iron in nearly equal proportions. Besides iron and nickel, 24 other terrestrial elements and 2 minerals not existing in the earth's crust have been found in meteorites.

In ancient and mediaeval times, the passage of a brilliant fireball or of great meteoric showers or the fall of a meteorite was viewed with superstitious awe. Such phenomena are now objects of keen delight, and astronomers observe and study them at every opportunity. An extraordinary meteorite fell in 1931 in the extreme south of Tunis. It rushed through the sky with a blinding flash and a thunderous sound and burst into fragments in mid-air. On the site of the fall, cavities were noticed in the ground similar to those produced by a 75-millimetre (3 inches nearly) shell. Pieces were picked up by French officers who witnessed the phenomenon and were sent to the Museum at Tunis. Mons. Alfred Lacroix, the Secretary of the Académie des Sciences de France, subsequently visited the place and, after examining the fragments, sent a full report to that body. On 28th December 1931, a giant meteor as large as three times the apparent size of the moon was reported to have been seen at Lisbon passing over the city with the roar of an express train and lighting up the country for miles around. It is believed to have fallen in the Atlantic.

According to Gregory, something like 400 million meteors—solid particles each weighing only a few grains—enter the atmosphere daily. Dr. Harlow Shapley, Director of the Harvard Astronomical Observatory, who is recognized as the greatest of modern American astronomers, goes still further and puts down the probable number at one billion!

(12) Average Height of the Ozone Layer above the Earth's Surface } 50 km. = 31¼ miles

Note.—According to one authority, the lowest height of this layer above earth is 20 km. and its greatest height 80 km. This estimate gives an average height for this layer of 50 km., which is exactly the value determined by F. W. P. Götz and G. M. B. Dobson in 1929 as its average height.

The sun's ultra-violet rays break down the oxygen molecules of the air into atoms, and the latter combine with the unbroken molecules of oxygen in the atmosphere to form ozone. This 'ozone-blanket' absorbs a great deal of the ultra-violet radiation and prevents an excess of it reaching the earth. Too much ultra-violet sunlight would be as bad for living beings as too little. Were it not for this ozone-blanket which absorbs so much of the sun's ultra-violet radiation, it is said that every living being on the earth would become blind by their effect.

Both from observations by means of sounding balloons as well as from the reflection downward of the sound waves produced by an explosion it has been found that the Stratosphere is not, as hitherto supposed, a strictly isothermal or constant temperature layer but that the temperature in it slowly increases with height, though up to what height it does so it has not yet been determined. This gradual increase of temperature is attributed partly to absorption by the Ozone Layer of the incoming and outgoing radiations.

(13) Height at which average Shooting Stars disappear in their fall } 50 miles

(14) Approximate Height of the Heaviside Layer } 45-65 miles at evening & 60-85 m. in early morning

Note

Since the day when Marconi, the inventor of wireless telegraphy, first established a two-way communication between England and America, the mode of propagation of radio signals round the curved surface of the earth has been engaging the attention of scientists the world over. It has thus been discovered that the atmosphere at great heights is in a permanent state of conductivity—a phenomenon ascribed to the presence of ions or charged electric particles into which the air gases break up under the influence of solar agencies. Radio waves shot out from a transmitter travel along bands of these particles and are reflected back to earth. These waves, unlike waves of light, follow the curvature of the earth's surface. The conducting layer is called the Heaviside or Kennelly-Heaviside

Layer, so named after Dr. A. E. Kennelly, Professor of Electrical Engineering at Harward University, and Professor Oliver Heaviside, a British physicist, who discovered it some 25 years ago. This layer prevents the escape of the radio waves into space and makes long-distance radio possible. From the fact that the solar agents mainly responsible for the ionization in the upper atmosphere travel in a rectilinear course it is inferred that this ionization is produced by the ultra-violet rays and fast-moving material particles shot out from the sun, and the evidence from so important bodies as the Bureau of Standards of Washington and National Research Council of Canada definitely establishes the importance of ultra-violet radiations as the chief ionizing agency for the Heaviside Layer. The height of this layer varies from day to night. Dr. Harlan T. Stetson, Director of the Perkins Observatory at the Wesleyan University, Delaware, Ohio, considers that the moon also plays a part in regulating the height of the 'Radio Roof'. The persistence of the conductivity of the upper atmosphere during night must be due to the fact that, at the low pressures prevailing at heights of the order of 100 km., the frequency of molecular collisions will be small and the average life of an ion will therefore be long.

At an instructive lecture delivered at the 19th Session of the Indian Science Congress held at Bangalore in January 1932, Professor S. K. Mitra of Calcutta University gave an account of the extensive experimental work done by him to ascertain the height of the conducting radio atmosphere in Bengal. The height has been found to vary from 45 miles in the evening to 60 in the early morning, against about 65 and 85 miles respectively in England. The Professor has been experimenting with echoes of wireless signals to measure the heights of the layer. His method is an adaptation of that recently developed by Dr. E. V. Appleton, Wheatstone Professor of Physics at the University of London, during his experiments at the Slough Radio Research Station. It consists in sending out electro-magnetic wave trains of short duration from a transmitter and capturing the waves, along with the echoes caused by their reflection from the Heaviside Layer, by means of a specially designed receiver placed a few miles away. A remarkable feature of these echoes is that sometimes the echo is found to be stronger than the signal directly received, and further, instead of a single echo,

very often two, three or four echoes are received in rapid succession. The abnormal strength and multiplicity of these echoes have been found to be most pronounced during the 10 to 25 minutes immediately preceding sunset. Mitra referred to a remarkable class of long-delayed echoes recently discovered by the distinguished Norwegian scientist, Professor Carl Störmer. These echoes were found to return to earth several minutes after the signals producing them had left the transmitter. During all this interval the signals must have travelled vast distances in outer space. There was considerable speculation as to their origin. It was supposed that far outside the moon's orbit, the ions continually present in space formed themselves into a sort of layer or band by magnetic influence and that the echoes were probably due to the reflection of the wireless wave trains meeting this ionic band. One could gather some idea, concluded the lecturer, of the enormous distances involved if one realized that, if the sound of a gunshot were to travel by the same path as followed by these waves, it would take five years for the sound to come back to the earth as an echo!

The height of the Heaviside Layer is greater at night than during day. The alternate increase and decrease in height are not gradual but rapid.

(15) Aurora Borealis or Northern Lights, and Aurora Australis or Southern Lights	About 80-106 km. = 50-66 miles (*Encycl. Br., 1929*)

Note

Aurorae are a luminous phenomenon of the atmosphere. According to Störmer and many other scientists, they are caused by electric corpuscles shot out from the sun. These corpuscles strike the earth's atmosphere and flash into the brilliant displays known as the Aurora Borealis in the northern hemisphere and Aurora Australis in the southern hemisphere. Aurorae are among the most spectacular of Nature's exhibitions of fireworks. Long rays like the beams of a powerful searchlight, assuming a variety of colours, roll up in great fan-like sheaves towards the zenith from a dusky line of cloud or haze a few degrees above the horizon. At times, as they sweep upward, they shake with a tremulous motion and, according to some observers, are accompanied by crackling sounds like the rustling of

pieces of silk against each other. This curious sound is referred to in *Mazeppa's Ride* by Byron :—

'We sped like meteors through the sky,
When with its crackling sound the night
Is chequer'd with the northern light.'

In order to study the aurora, it is photographed with its background of stars from two different positions between 25 and 50 miles apart. When simultaneous photographs are taken in this way, the position and the height of the aurora from the earth's surface can be calculated. The lower edges or streamers of an aurora have thus been found to be at a height of 50 to 66 miles above the earth.

Aurorae are of many types and sometimes appear in several forms at the same time. They are known as rays, bands, curtains, draperies, arches, coronas and diffuse glows. A faint aurora is usually white, a fairly bright one yellowish, and a very bright one multi-coloured, red and green predominating. The display is seen in its greatest splendour in the form of a bright arch, especially when it extends, as it frequently does, right across the sky from east to west. At such times it appears in red, yellow and green colours much like a rainbow. In the polar regions five arches have been observed at the same time. On one occasion, in February 1929, an auroral arch at the height of its brilliancy flung a straight subsidiary arm from its western end. This arch, at the time of fading, was seen to assume a sinuous form, suggesting a 'drapery' appearance.

Even when very bright, an auroral arch or curtain is quite transparent and stars are seen shining through it in its entire length.

Opportunities for witnessing the Aurora Borealis are more frequent as one goes northwards from countries in the Temperate Zone, till along a belt called the auroral zone, the lights become visible on every clear night. Störmer showed some years ago, by scientific models of the path of the ionized particles ejected from the sun, that these were caught in the earth's magnetic field and whirled about our globe in belts of varying width, centred at the pole of the earth's magnetic axis, about two-thirds the way to the geographical Pole. An aurora can thus practically circle the entire earth at once. The Aurora Borealis and the Aurora Australis may occur simultaneously. But the former is said to be the more magnificent of the

two. The auroral zone here passes north of Siberia and Norway, south of Iceland and Greenland, and over Northern Canada and Alaska, the latitude of greatest frequency of the display being about 70° N. for Asia and Europe and 60° N. for America. In these regions the sight is often magnificent in form, colour and motion.

Montgomery gives a vivid, though short description of this grand phenomenon :—

> 'Tis sunset : to the firmament serene
> The Atlantic wave reflects a gorgeous scene ;
> Broad in the cloudless west, a belt of gold
> Girds the blue hemisphere ; above unroll'd
> The keen clear air grows palpable to sight,
> Embodied in a flush of crimson light,
> Through which the evening star, with milder gleam,
> Descends to meet her image in the stream.'

Störmer, who has been closely observing the Aurora Borealis for many years, has found that very high aurorae, which sometimes do not come below 120 miles and extend upward for 500 miles, are still in the sunlight though observed from countries in the night hemisphere ! For example, on 16th March 1929, three hours before dawn, pale grey-violet rays of aurora suddently appeared in the north-east and were found to be so high that they were bathing in sunshine. Occasionally such rays become faint or totally disappear where they meet the line of the earth's shadow, and are continued still lower down, with normal brightness at the usual height of aurorae.

According to Humphreys, much of the light of the aurora is due to nitrogen bands and none of it to hydrogen lines, while the brightest of all lines is due to oxygen 'presumably in a special state', and its brightness is probably intensified by the presence of helium.

(16) 'Beware! Danger overhead!' roars out the Voice,
'Thus far and no further!' —

'*Roof*' of the Stratosphere, or End of the Earth's Atmosphere . } 49-71 miles

Note.—The pressure at an altitude of 71 miles, according to Humphreys, would be between 1/146000th and 1/129000th of that at sea level.

Concluding Remarks

Below the Stratosphere the temperature of the air falls with increase of altitude, but in this upper layer the temperature gradient, at least up to the height so far gauged, shows a reverse arrangement from that in the Troposphere. The Stratosphere is a curved layer running somewhat parallel to the earth's curved surface. Its general height gradually falls off from the equator. According to Humphreys, the altitude of the lower surface of the Stratosphere is 15 km. (9 miles 3 f.) at the equator and about 10 km. (6 m. 2 f.) at latitude 60°. But in view of the report that a sounding balloon has recorded a temperature as low as -92° C. (-133° F.) at a height of 11 miles at the equator, it is probable that the Stratosphere over the equator begins a little beyond this height. As for the base of this layer in the polar regions, a recent estimate assigns to it a height of 8½ km. (a little over 5¼ miles) after about 80° lat. We have therefore adopted the approximate average value of 45,000 ft. as the point at which the Stratosphere commences. Mr. Luckiesh remarks that there is less difference between the summer and winter temperatures of high altitudes than of low ones.

A few words of explanation are necessary about the Tropopause. Strictly speaking, the Stratosphere rises immediately above the Troposphere, but certain authorities add an intermediate region between the two and call it the Tropopause. They describe it as the boundary region or rather the 'surface' which divides the two layers. Now a surface, in the strict geometrical sense, is an area having only length and breadth but no thickness. Most scientists assign to the Troposphere a height of 6 to 7½ miles, and although during the past few years several airmen have crossed this limit and a few have flown to altitudes as high as 8 miles, scientists have all along been talking of penetrating into the Stratosphere. Thus when Piccard made his remarkable balloon ascent in 1931, his flight was represented as the first penetration by man into the Stratosphere. We have therefore thought fit to recognize the existence of a boundary region between the two layers and at the same time to assign to it an artificial thickness—an average thickness of about 6,700 ft., which represents the difference between the average altitude of the base of the Stratosphere and the height of the Troposphere.

Various estimates are put forward for the top limit of the Stratosphere. It is calculated by observations of either meteors or aurorae or by measurement of the duration of twilight. Lindemann and Dobson, the well-known astronomers, have inferred from observations of meteors that this layer does not extend beyond about 37½ miles, while another astronomer states that similar observations made by him show that it ends at 30 miles. The highest estimate we have come across for the height of the upper boundary of this region is 50-60 miles. But for reasons explained in the following paragraph, we are inclined to adopt 48-71 miles as the point where the Stratosphere ends.

We have seen that the usual height above earth at which an auroral display begins is 50 to 66 miles or an average of 58 miles. The descriptions we have come across of this phenomenon are unanimous in stating that the initial motion of the streamers is always upward. It thus follows that, if the phenomenon is caused by the ionized particles from the sun bombarding our upper air, the aurora takes its birth at the top of the earth's atmosphere and not at that of the *whole* Atmosphere. Störmer's explanation, so far as this point is concerned, is therefore clear. An aurora, owing to its much longer duration, must be less difficult to study than the evanescent displays of meteors in determining the probable height of the earth's atmosphere, *i. e.*, the upper limit of the Stratosphere. It is therefore permissible to infer that the top boundary of this layer lies at the points where the auroral display begins, *viz.*, 50 to 66 miles above the earth. This limit will apply only to those regions through which the auroral zone passes, *i.e.*, latitudes 60^0 to 70^0 N. and 60^0 S. The Stratosphere being, as stated, a curved layer running somewhat parallel to the earth's curved surface, over the polar regions it begins at 5½ miles and over the equator at about 11 miles as already mentioned. Its upper limit in the former regions will therefore be between 49 and 65 miles and over the latter region between 55 and 71 miles above the earth.

It is well known that astronomy, along with many other branches of science, formed an important intellectual pursuit among the ancient Hindus. Long after Parāshara, the last great astronomer of olden times, whose date is located at about 1391 B.C., came the famous Aryabhatta (born about 476 A.D.) and Varāha-

mihira (born about 485 A.D.). The last of our eminent savants in this field of learning was the great mathematician-astronomer, Bhāskarāchārya, who was born about 1114 A.D. and died some time after 1185 A.D.

Aryabhatta and Lalla, the latter of whom lived about 638 A.D., estimated the limit of the earth's atmosphere at 12 *yójanas*, *i.e*, about 60 English miles. This estimate is confirmed by Bhāskarā-chārya, who says in *Madhyagathivāsanā* :—

भूमेर्बहिर्द्वादश योजनानि ।
भूवायुरत्रांबुद विद्युदाद्यम् ॥

(*Bhūmērbahirdwādasha yójanāni bhūvāyurathrāmbuda vidyudādyam*), which means :—

'The atmosphere surrounds the earth, and its height is 12 yójanās, and clouds, lightning and other phenomena originate in it.'

The astronomer Shripati (born about 1039 A.D.) explains that clouds, lightning, rainbow, aerial mirages (*Fata morgana*, the original Sanskrit term being *Gandharvanagara*), haloes round the sun and the moon and shooting stars are all phenomena connected with the earth's atmosphere.

Further, Lalla, Shripati and Bhāskarāchārya have all advanced the view that, above the earth's atmosphere, lies another high layer of air.

In the 11th century A.D. the Arabs calculated the height of the earth's atmosphere from the duration of twilight to be about 57½ miles.

From their observations of the flights of meteors, Lindemann and Dobson confirm the presence above a height of 37½ miles (their estimate of the top limit of the Stratosphere) of a warm layer of air which, they say, extends up to the point where meteors first flash into brilliance, and they estimate its temperature at 80° F. (26·7° C.). This theory is in part supported by Dr. F. J. W. Whipple, Superintendent of the Kew Observatory in England, who, from his study of the strange phenomenon that sounds like those of gunfire are often heard better at a distance than by listeners at much nearer points, infers that this peculiarity is due to the existence of a warm layer in the upper air through which sound waves curve back

to earth. He assigns, however, a lower height above earth and a higher temperature to this layer.

The *Popular Science Monthly* of September 1931 gives particulars of an interesting experiment carried out by Whipple in this connection. He wanted to trace the path of the sound waves from an explosion between the moment of their generation and their reappearance miles away, after overleaping a 'zone of silence'. At an artillery practice at Yantlet he arranged to have radio signals broadcast the instant a gun was fired. At Birmingham, 230 miles away, and at intermediate points he set up super-sensitive microphones to catch the inaudible sounds of the explosions. Then he timed the arrival of the sound wave and checked it against the almost simultaneous receipt of the radio signal. From the speed of sound in air he found that the length of time taken by the sound wave to arrive could only be explained by assuming that it travelled into the sky to a height of about 30 miles and then descended to reach the Birmingham microphone, skipping intermediate points. He considers that the descent of these sound waves back to earth is due to their being reflected downward from a warm layer of air in the Stratosphere. The sound waves in this experiment were found to travel in a curvilinear course, almost hyperbolic. The tests showed that this layer of air must be as warm as 106° F. (41° C.). Whipple's experiment is especially interesting as we find that the highest point above earth calculated to have been reached by the sound waves falls within the region of the warm Ozone Layer.

Second International Polar Year

Concerted effort to obtain data from the Polar upper air is being made by scientific expeditions from Great Britain, France, Holland, Denmark, Norway, Sweden, Finland, Russia, Poland, Germany, Italy, Canada and the United States of America in celebration of the First International Polar Year of 1882-83. In that year twelve countries including Great Britain joined hands and sent special expeditions to the Arctic and Antarctic regions to carry out, mainly meteorological and magnetic observations, on a settled plan. The results obtained were of considerable scientific value and laid the foundation for subsequent research into the physics of the atmosphere

and terrestrial magnetism in the Polar regions. The progress in geophysics since that time has shown the great importance of polar data, and hence it is that the various countries have arranged expeditions, which will set up a network of temporary observatories in a circle round the North Magnetic Pole to carry out extensive and intensive research. A Norwegian expedition has arranged to proceed to Antarctica for simultaneous meteorological observations in that region. It will travel by sledge along the coast of that continent. The research work of the Second Polar Year will not be confined to meteorology as understood in the strict sense of the term, but will include observations of the important phenomena of terrestrial magnetism and atmospheric electricity and deeper investigation of the nature of that flaming marvel of the northern skies—the Aurora Borealis—and its connection with the mysterious magnetic storms which sweep over the earth and cause compasses to swing violently.

These expeditions commenced their work on 1st August 1932, and it will last for 13 months. The British section consists of two parties, one of which will proceed to Tromsö in Norway and the other to the lonely settlement of Fort Rae which lies within the Arctic Circle on the Marian Lake extension of the Great Slave Lake in Northern Canada.

The expedition at Tromsö will investigate the ionized layers above the earth to find out whether there is any connection between the aurora and the Heaviside Layers, as many scientists think it probable that this layer is produced by the aurora. Tromsö is a place where the aurora is of frequent occurrence and there are no ultraviolet rays of the sun during the long period of the Arctic winter. These are conditions which are favourable for studying, by repeated measurements of the height and intensity of the ionized layers, how the ionization is brought about.

The British contingent to Canada consists of five men who include three scientists and is led by a senior scientific assistant of the Meteorological Office. Fort Rae, where there will be 80° of frost (–48° F. or –44.5° C.), is one of the coldest parts of the world, colder than even at the North Pole. The party will spend a year in this bleak, inhospitable region in the interest of science, completely cut off from civilization except for wireless. A complete record of wind direction and force, air temperature and height of

clouds will be made at hourly intervals. As at the other stations in the Arctic chain, sounding balloons filled with hydrogen and carrying automatic instruments will be sent up from this place to a height of 6 or 7 miles, and they may rise even 10 miles. They will be sent up at least once a day and their course followed by a telescope fitted with a theodolite which will indicate their direction. But as the recovery of the recording instruments after they come to the ground will be a most formidable problem in these uninhabited polar regions, the extensive use of radio transmission apparatus which will automatically signal to listeners on the ground the air temperature and pressure at various heights—*vide* Item 1—is contemplated in spite of their heavy cost. Alternately other balloons will effect the same result by flashing coloured lights. Research into the physics of the aurora will also be one of the activities of the Fort Rae expedition, as this place offers the special advantage of being situated almost in the zone of maximum frequency of aurorae.

Improved methods of investigation, undreamt of in the days of the First Polar Year, being now available, the hourly observations of terrestrial magnetism will be dispensed with and replaced by magnetographical records.

Where mountains exist in proximity to stations established closer to sea level, special observatories will be set up to take records of temperature, humidity, wind and cloud motion. An amount of valuable information will thus be obtained about the physical conditions of the Stratosphere in high latitudes, of which very little is known at present.

The work of organizing the various expeditions has been entrusted by the International Meteorological Organization to an executive body called the Polar Year Jubilee Commission. As investigations of geophysical phenomena in high latitudes alone would not be of as much scientific value as simultaneous observations throughout the earth, the Commission has invited the active co-operation of all the meteorological services of the world, and besides the countries already mentioned, many others including Austria and Japan have signified their intention of participating in the work of the Second Polar Year. The Indian Meteorological Department has also been asked to cooperate. Among other activities which this Department has been requested to undertake are the sending up of sounding and pilot

balloons for about 80 days during the Second Polar Year (August 1932–August 1933) and regular magnetic observations at the observatory at Alibag. This is the only Magnetic Observatory in India taking continuous records of all the magnetic changes and has the advantage of being situated on the magnetic equator.

The results of all the observations made during the Second Polar Year are required to be published almost immediately after their cessation and in a uniform style. It is expected that the Polar observations will promote a better knowledge of the movements of the upper air. According to the laws of physics, the warm air of the tropical regions must tend to rise and flow towards the Poles above the cooler air which moves inwards to replace it, so that there is a general circulation of the atmosphere throughout the earth. The earth, in the words of Dr. Simpson, Director of the British Meteorological Office, may be likened to a heat-producing engine with condensers at the Poles, and all the energy required to produce the winds is generated by the heat of the Equatorial regions and by the cooling of the air near the Poles. But the velocity, extent and exact directions of the upper air movements form one of the mysteries of climatology that remain to be satisfactorily solved. It is anticipated that simultaneous and comparative observations over the Polar cap as well as in lower latitudes during the Second Polar Year will enable the meteorological services everywhere to draw up more accurate weather forecasts than has hitherto been possible.

Meanwhile comes the news that Russia has established a meteorological station at Teplitz Bay in Crown Prince Rudolf Land, situated approximately in 81° 20′ N. lat. This station is situated even farther north than the weather station in Franz Josef Land (about 81° N. lat.) and is now the northernmost meteorological station in the world. It will be remembered that the snowline in latitudes above 75° is at sea level, so that these two stations are situated in regions of perpetual snow like the Monte Rosa observatory in the Alps.

View from the Mid-Stratosphere

The warnings of the mysterious Voice from the Sky, though we are now fairly well accustomed to its menacing tones, make us

hesitate about continuing our ascent. Before coming to a decision, therefore, we descend to the mid-stratosphere and 'station' ourselves there for a whole month! Looking north, east, south and west as well as overhead and below through the huge glass windows of our balloon car, let us observe closely the landscape and skyscape presented to us from this region of the sky.

Owing to the absence of fogs or clouds around or above, the sun emits the harsh glare of a searchlight. We see the sun here at all times during the day, and such will be the case throughout the year. Our horizon distance is something like 500 miles. In ordinary weather an observer looking below from such a height will see only such portions of the ground as the rifts in the clouds will expose. But better luck favours us at the time of our return to this region, and the terrestrial weather is perfectly clear. Yet we find it impossible to distinguish any landmarks. Lakes and rivers are virtually wiped out of existence under the sun's rays and appear as scattered, dazzling spots or streaks. Mountains seem to have sunk into the earth. Ground, forests, valleys and trees, all practically merge themselves into one confused whole, and the earth's land surface presents the appearance of a flat plain. We proceed seaward and arrive directly above the coast shortly after noon. The sea presents itself to us, not as a blue expanse of water but as a burnished silvery mirror bounded by an irregular and indistinct coast-line and the horizon. To us temporary tenants of the upper atmosphere this is all that is visible of the planet on which we were born and which we left not long ago. The skyscape in daytime is different from what we have been accustomed to on the earth, for on account of the high rarefaction of the air and the considerable diminution, in consequence, in the scattering of sunlight, the principal stars and planets are visible to us even by day, though somewhat faintly.

It is night. The moon is at its full phase, and its disc appears in all its splendour, revealing its surface in greater detail. On the earth the moonbeams reach us after being filtered through the clouds and the dust particles of the atmosphere. Rising air currents together with layers of unequal temperature and humidity cause variations in the density of the air through which the light of the stars comes to us. Stars for this reason twinkle or scintillate when seen from the earth, but from the Stratosphere we see them

shine with a steady, intense glow like rubies set in the background of the sky.

A fortnight has passed. It is a clear moonless night, and lo, for a whole night Nature entertains us with a superb display of her fireworks! The blue-black sky is illuminated by shooting stars speeding across with a frequency inconceivable to those on the earth, and once or twice by groups of brilliant fireballs sometimes looking larger than the moon—some disappearing far above our altitude, some close overhead and others down at our feet! And the streaks of splendour in which the shooting stars end their career and the luminous clouds that the fireballs leave in their trail appear to set the sky ablaze, enhancing the magnificence of the whole scene.

CHAPTER IX

The Outer Atmosphere

(1) Height above which the Sky would no longer look blue-black but would gradually have changed to jet-black — 71 miles

Note.—Sunlight can be decomposed into a range of colours. What we see as white or colourless light is resolved into different colours when a sunbeam strikes a glass prism or the bevelled edge of a mirror. The most magnificent indication in Nature of the colour composition of sunlight is that presented in the rainbow (called by the ancient Hindus *Indradhanus*, the bow of Indra, the god of clouds and rain). In this phenomenon the sunbeams are refracted and dispersed by tiny drops of water in the clouds, and the white sunlight in reaching us is split up by the raindrops into the seven primary colours—violet, indigo, blue, green, yellow, orange and red. Not only are these colours found in every shade in a sunbeam, but where one primary colour follows another an intermediate colour is present between the two. These colours are arranged consecutively as follows: violet, indigo or blue, blue-green, green, yellow-green, yellow, orange and red. The shortest waves of visible light produce the impression of violet, and the longest red. Still shorter than the violet rays are the invisible *ultra-violet.* Waves longer than those which give red light are called *infra-red*, but though infra-red rays are not perceptible to the human eye, it seems possible that the eyes of animals of the feline race are responsive to them. These rays are said to pass with ease through haze, mist or fog which completely intercept white light. The approximate wave-length of ultra-violet light just beyond the visible region is 1/64000th of an inch, and the wave-lengths of the other rays increase from violet to red. The wave-length of infra-red light just beyond the visible region amounts to 1/31000th inch.

The sky looks blue from the earth owing to the scattering of sunlight by the earth's atmosphere. The atoms and molecules of its gases are so minute that they scatter this light in every direction;

The scattering is more efficient when the waves are short than when they are long, and so the blue and violet rays are scattered more than the yellow and red. The greater scattering of these short waves makes the sky appear blue as seen from the earth. But owing to the decrease in the amount of air present above, the scattering of sunlight becomes smaller and smaller as we go up in the atmosphere, and the sky would therefore appear jet-black after the boundary of the earth's atmosphere is crossed.

(2)	Height at which average Shooting Stars flash into view	75 miles
(3)	Greatest Height at which Meteors have become visible	120 miles (*Encyd. Br., 1929*)

Note.—At this height the air would be about twice as thin as that inside a vacuum lamp-bulb or about 1/2-millionth of that at sea level, and yet it is evidently dense enough to cause meteors to flash into view. The higher the point at which these objects become visible, the greater will be the grandeur of their display, particularly when they shoot across in a shower. A beautiful shower of Leonids, the best-known of all meteor streams, was seen in 1863 at a height of 96·3 miles, and at this display no fewer than 78 meteors were counted. A graphic description is given by Ball of a remarkable meteor seen on 6th November 1869 at a height of 90 miles above Frome in Somersetshire. The whole length of its visible course was about 170 miles, which was traversed in 5 seconds, *i. e.*, at an average velocity of 34 miles a second. A rare phenomenon which followed its disappearance was a long persistent streak of luminous cloud, about 50 miles long and 4 miles wide, which remained in sight for fully 50 minutes.

(4) Appleton Layer or 'New Radio Roof' ... 130 miles

Note—The *Illustrated Weekly of India* of 13th December 1931 contains some particulars of the discovery of a 'New Radio Roof' made by Professor Appleton. This discovery makes the Heaviside Layer (Item 14 of the preceding chapter) the base of the whole 'Radio Roof'. Very short waves have been found to pass through this lower layer and be reflected back to the earth from the upper layer, which will henceforth be called the Appleton Layer. It ends at 130 miles above the earth. Its height was determined by the transmission of a signal, lasting less than the thousandth of a second, which pierced the Heaviside Layer and travelled far beyond. "These two layers play a vital part with "fading" in wireless reception. One of the scientists at the research station spends his

days watching the tiny green spot bobbing on the end of a great wireless valve. By observing its movements he hopes to reduce fading to a mathematical formula.' The station referred to is the Radio Research Station at Slough in England.

It may be mentioned that while light waves are of exceedingly minute lengths, even the shortest of wireless waves are a few inches long and the wave-length of some long-wave broadcast stations is as much as 20,000 metres or over 65,000 ft!

As in the case of the Heaviside Layer, the evidence from the National Research Council of Canada definitely points to the importance of ultra-violet rays as the principal ionizing agency for the Appleton Layer, though physicists are of the opinion that the last word has not been said as to the relative importance of the two solar agencies in producing these two layers.

The ionized regions of the Atmosphere are sometimes collectively termed the Ionosphere.

(5) Height which the diffused light of the highest streamers of an Auroral Curtain has been found to reach } 600-620 miles

Note.—The *Encycl. Brit.* (1929) mentions an unusual auroral display observed west of Norway on 8th September 1926. It appeared like an arch, but the photographs showed that it was made up of a curtain of rays which extended to a height of 187½ miles. The *diffuse form* which ended the display reached a height of 600 miles. Störmer, as already mentioned, has observed auroral *streamers* 500 miles in vertical length with their base 120 miles above the earth, so that they attained the record height of 620 miles above the earth. We are not sure whether or not the display referred to by the *Encyclopaedia* is the same as the one observed by Störmer.

(6) 'Halt, halt, as ye value your lives!' bellowed the Voice, 'Car windows cracking, oxygen tanks leaking! What? Still thinking of moving on? Ha, ha, ha! Only hydrogen and helium to breathe ahead, if ye could stand the zero pressure!'—

'Roof' or End of the *whole* Atmosphere } 620 miles or more

Note.—It is generally believed that the greatest height which an auroral display can attain marks the limit of the Atmosphere. Dr. Baker infers from the results of Störmer's observations that it is probable that the Atmosphere extends, highly rarefied, to a still greater height than 620 miles.

Concluding Remarks

Abbé Th. Moreux considers that hydrogen envelops the Stratosphere in the shape of a warm layer above it. As will have been seen from the Note under Item 5 of this chapter, this gas is present only in very minute proportions in the air we breathe. The rest of the hydrogen content of the Atmosphere may be miles up in the rarefied regions and cannot descend far owing to its extreme lightness. The study of aurorae, adds Moreux, indicates that this is true. Partington believes that, at a height of 62 miles, 96 per cent of the air would consist of hydrogen.

It is believed that the temperature in the Outer Atmosphere is practically constant.

Let us now try to ascertain the approximate weight of the Whole Atmosphere, which extends from the base of the Troposphere up to 620 miles or more above the earth's surface. The method of calculation is similar to that adopted by us in 'weighing' the Ocean. Just as we took the average depth of the sea in that calculation, in this case we have to take the mean pressure of air at the earth's surface, which has been found to be about 14·3 lbs. per square inch, against 14·7 lbs. at sea level. We have now only to multiply the superficial area of the earth (199,199,625 sq. m.) by this average air pressure (the former being converted to square inches and the latter reduced to the fraction of a ton), as the pressure at any area represents the weight of the column of air over it. The result thus obtained is *5·1 quadrillion tons*, a value which is only about 10 per cent higher than that given by Humphreys in his *Physics of the Air*. The weight of the Atmosphere is thus about ·0037 that of the Ocean and approximately ·0000008 that of the whole Earth.

We may similarly endeavour to arrive, however roughly, at the weights of the individual constituents of the Atmosphere on the data given by Humphreys. He estimates the average amount of water-vapour in the atmosphere to be the equivalent of a layer of water over the whole earth only [illegible] centimetres (1·02362 inches) deep. Taking the weight of a cubic foot of pure water as 62·4 lbs. approximately, the weight of the water-vapour in the atmosphere will thus amount to

$199{,}199{,}623 \times \frac{[illegible]}{12 \times 5280}$ (reducing the inches to the fraction of a mile) $\times \frac{62\cdot4}{2240} \times 5280^3 = 13\cdot2$ trillion tons.

Working on an equation given by Humphreys, the physical and mathematical intricacies of which need not be set forth here, we obtain the following values for the weights of the remaining components of the atmosphere, though they are about 10 per cent higher than those arrived at by him:—

Constituent	Weight in Tons	
Nitrogen	3·87	quadrillion
Oxygen	1·15	"
Argon	61·76	trillion
Carbon dioxide	2·16	"
Hydrogen	128·8	billion
Neon	68·8	"
Krypton	12·8	"
Helium	7·95	"
Ozone	2·98	"
Xenon	1·69	"
Total	5·084143	quadrillion tons.

If we add to this total the weight of the water-vapour, *viz.*, 13·2 trillion tons, we get a grand total of 5·097343 quadrillion tons, almost exactly the weight of the Whole Atmosphere. The weight of the hydrogen content especially is noteworthy. It affords material for a startling comparison. According to the estimates of the International Statistical Institute, the world's total population in 1926 was 1,879,595,000 or approximately 1,880 millions. Assuming that this total remains unchanged and that the average weight per head is 60 lbs., the weight of the world's population will amount to about 50 million tons. Allowing for the excess of 10 per cent in the figures shown in the foregoing table, we find that the weight of all the hydrogen in the atmosphere, in spite of its being the lightest of gases, is at least 2,300 times the weight of the entire population of the world!

The mysterious Voice once more administers to us a warning, this time a most stern warning. Should we not pay heed to it in our perilous situation and turn back? But before finally making up our mind, let us descend a couple of hundred miles,

It is a dark night, and from these lofty regions so far away from the Stratosphere we behold a strange spectacle. Once again Nature is out with her fireworks exhibition, but at the immense height of our observation-point, the luminous tracks of the thousands of meteors that shoot across look only like so many tiny threads of flame. This time the heavens seem completely topsyturvy, for the meteors flash to our view and dissipate themselves at the bottom of a terrific abyss.

The complete absence of tropospheric phenomena in the Stratosphere onwards is worthy of note. But even about parts of the Stratosphere it is not possible to say definitely that no sounds whatever can be heard there at any time. The larger fireballs usually produce a thunderous roar as they strike the earth's atmosphere and rush earthward, and most of them ultimately burst with a loud explosion, and the common shooting stars as they speed through the sky possibly give rise to a sort of hissing sound more or less audible in the close vicinity of their tracks in parts of the Stratosphere at any rate. But in the loftier regions of the Outer Atmosphere we find conditions totally different. We are impressed with the perfect calm and silence that reign here, and well may we sing with Tennyson :—

'The lucid interspace of world and world,
Where never creeps a cloud or moves a wind,
Nor ever falls the least white star of snow,
Nor ever lowest roll of thunder moans,
Nor sound of human sorrow mounts to mar
Their sacred, everlasting calm !'

CHAPTER X

The Planetary Region

Heaven
Is as the book of God before thee set
Wherein to read His wondrous words.

— *Milton*

To rise in science, as in bliss,
Initiate in the secrets of the skies!

— *Young*

(1) Height over the equator from which, at an aurora circling the Earth, the Aurora Borealis or the Northern Lights, and the Aurora Australis or the Southern Lights, would be visible simultaneously	About 830-950 miles

Note.—In America the scene of the auroral occurrence is 60° N. or S. lat., so that the Aurora Borealis and the Aurora Australis occur in regions equidistant from the equator. The shortest distance pierced by a straight line drawn from a point on the equator to the region of the occurrence (for the earth's surface is curved) would be 2,633 miles, as the earth's polar radius is 3,950 miles. Could an observer rise vertically, say, 830 miles up from this point, his horizon distance from his 'station' in the sky would be about 2,730 miles,* and he would thus see, at an aurora circling the earth, the Northern and the Southern Lights at the same time. But for the Eastern Hemisphere, the region of the Aurora *Borealis* is lat. 70° N., and consequently an observer in this hemisphere would have to rise from a place 5° north of the equator if he wanted to reach an observation-point equidistant from the two Aurorae. In this case he

* Where the height of an observer is some hundreds of miles above the earth, the formula to determine his horizon distance would be $\sqrt{h\,(2r+h)}$, where h is the height in miles, and r is the earth's radius. In the present case we have to calculate the heights from the horizon distances by using this formula.

would have to command a horizon distance of a little more than $\frac{11}{16} \times 3{,}950 = 2{,}853$ miles. An elevation of something like 950 miles would be sufficient for the purpose.

(2) Elevation from which an observer would, except near noon, see Night, Dawn and Day on the Earth simultaneously if the atmosphere were perfectly clear } 1,500 miles

Note.—Mr. Luckiesh says in his *Book of the Sky* :—

'While on the wings of imagination, one might rise to an altitude of 1,500 miles, whence his horizon circle would nearly equal a great circle of the earth. His line of vision, when gazing toward the edge of the distant earth, would make an angle of about 45° with the vertical. It may aid visualization of such an imaginary view of the earth to place the eyes 3 ft. vertically above a horizontal circle 6 ft. in diameter. This circle subtends approximately the same solid angle at the eyes that the earth would when the eyes were 1,500 miles above it. Imagine a map of the Western Hemisphere drawn on this circle and that, as the eyes rove over it and leave its edge, they look into the void of space. At any time except near noon, the observer at an elevation of 1,500 miles would see night and day simultaneously on the earth. Perhaps day over the Atlantic, dawn over the Continent, and moonlight over the Pacific.

'In the foregoing views a perfectly clear atmosphere is assumed. The earth would still be veiled in the blue of clear air. Under the conditions as they actually are, the earth haze would add a white luminous veil, so that the details of the earth would be very much befogged.'

What must be the degree of rarefaction of gases or 'emptiness' of space at so great a height above the earth? Some idea of it may be gained from what Jeans says about the conditions probably obtaining at a height of 3,200 km. (2,000 miles). According to him, at this level there can only be roughly 300,000 gas molecules per cubic centimetre, that is to say, in the neighbourhood of *5 million* molecules per cubic inch. By means of an instrument known as the ionization manometer of a new design similar in construction to a radio tube, two scientists of the Bell Telephone Laboratory at New York, Dr. Edwin K. Jaycox and Dr. H. W. Weinhart, have

found, after having pumped out the last traces of air from a vessel and thus produced as perfect a vacuum as can be artificially created, that there were still left in the vessel some *500 million* molecules in every cubic inch. This amount, though seemingly large by itself, is said to be only 1/3-trillionth of the amount of air originally contained in the vessel. This means that every cubic inch of air at the earth's surface contains some *1·5 sextillion* molecules, against only *5 million* said to exist in space at a height of 2,000 miles! This latter quantity is equivalent to 1/100th of what would ultimately remain in the lowest vacua attainable in the laboratory. From this can be clearly understood the significance of the remark that space at such heights will be more void than that inside a vacuum lamp-bulb.

	Approximate distance from the Earth's surface
(3) Moon when it is simultaneously in perigee, *i.e.*, nearest to us in the course of its revolution round the Earth (in an elliptical orbit), and is crossing the zenith	213,500 miles

Note.—Such an event occurs at intervals of about 18 years and 11 days. The moon being then directly overhead, the observer is at the nearest possible distance from it. The moon's perigeal distance here is diminished by 4,000 miles, a little more than the earth's radius.

(4) Moon when in perigee but not crossing the zenith	217,500 miles

Note.—Such an event occurs once in a period of 27·3 days or a sidereal month, the time it takes to make one complete revolution round the earth.

When the moon comes between the earth and the sun, so that its dark side is turned towards us, it is said to be at conjunction. It is then called New Moon. If we could transport ourselves to the lunar world at such a time, we would behold a magnificent spectacle denied to inhabitants of the earth. Framed in a pitch-black firmament would be seen a huge, beautifully illuminated, bluish disc having a diameter nearly four times that of a full moon as seen from our globe and shining with a brilliancy nearly three times richer. We would thus see the surface of this hemisphere

of the moon flooded with light. What could that remarkable, distant object be? It is the *earth*! This flood of 'earthlight' on the moon is something like 40 times as much as full moonlight on the earth. The reason is that the earth is at once a larger and better mirror than the moon, better as it reflects nearly one half of the light received by it from the sun. The pale light visible from the earth at new moon is only a portion of this glorious earthlight reflected back to the earth itself.

The reason why our planet emits a bluish light is that a considerable proportion of its light is reflected by the dense layers of its atmosphere, and in earthlight therefore the blue of the sky is present to a greater degree than any other colour.

How would the earth look from the moon if observed in daytime through a telescope? Says Ball :—

> 'If any one stationed on the moon were to look at the earth through a telescope, would he be able to see any water here? Most undoubtedly he would. He would see the clouds, and he would notice their incessant changes, and the clouds alone would be almost conclusive evidence of the existence of water. An astronomer on the moon would also see our oceans as coloured surfaces, remarkably contrasted with the land, and he would perhaps frequently see an image of the sun, like a brilliant star, reflected from some smooth portion of the sea. In fact, considering that much more than half of our globe is covered with oceans, and that most of the remainder is liable to be obscured by clouds, the lunar astronomer, in looking at our earth, would often see hardly anything but water in one form or other. Very likely he would come to the conclusion that our globe was fitted to be a residence for only amphibious animals.'

A description of the lunar landscape, and of the physical conditions obtaining on our satellite will be found in later chapters.

(5)	Moon when in apogee, *i.e.*, farthest from the Earth in the course of its revolution—an event which occurs also once in a sidereal month	248,747 miles
(6)	Distance from which, to a space voyager 'stationed' in the heavens, the Earth would periodically be visible as a shining orb of the same size as a Full Moon appears from the Earth	About 800,000 miles

Note

This distance is obtained by multiplying the moon's nearest distance (217,500 m.) by the length of the earth's mean diameter (7,918 m.) and dividing the product by the length of the moon's diameter (2,160 m.).

A space voyager soaring into the heavens and keeping more or less in the plane of the earth's orbit, would, if he observed the earth for a twelve-month, witness imposing changes on its face from the time it appears as a bright object. He would behold, with wonder and delight, our planet passing through the same cycle of phases as the moon does to an observer on the earth. He would see in succession a Crescent Earth, Half Earth, Gibbous Earth, Full Earth, and after a break due to the new phase the same changes in reverse order, a waxing and a waning Earth—strange, unfamiliar terms all! — as the earth moves in its orbit. If, however, he rises from the earth in a direction perpendicular to its orbit, neither the earth nor the moon will show to him any material variations in their phases. They will appear more or less as Half Earth and Half Moon all the time.

But coming lower down, if he continues to keep between the earth and the moon within certain distances from them, he will observe the various phases of both simultaneously. These phases he will find to be complementary to each other: when the moon is new, the earth will be full; when the moon is crescent, the earth will be gibbous; when the moon is half, the earth will also be half; when the moon is gibbous, the earth will be crescent, and when the moon is full, the earth will be new! The earth in its bright phases will shine with a bluish light for reasons explained under Item 4. Next in grandeur to its full phase will be the crescent, a great illuminated arch stretched across the black firmament, with a diameter (here the straight line joining the horns or cusps) varying according to the distance he keeps, from 5 to 10 times that of the crescent moon as seen from the earth. And further, if he keeps all the time at about four-fifths of the way to the moon, he will see both the bodies equal in size as they undergo their respective phases. Here the most unique will be the half phase, when he will see, as it were, two half moons of the same size at the same time, a bluish

giant on one side and a silvery giant on the other, and but for the colour he could not readily distinguish the one body from the other.

		Approximate distance from the Earth
(7)	Nearest Distance to which a Comet's head has ever approached the Earth	5 million miles

Note.— It was Laxell's Comet, and this record approach occurred on 1st July 1770. In Hindu Astronomy a Comet is known as *Dhūmaketu.*

(8)	Nearest approach to the Earth of an Asteroid (minor planet)	About 2·5 million m.

Note.— The object is the new asteroid discovered in May 1932 (see Chapter XV).

In Hindu Astronomy the asteroid is known as *Upagraha.*

(9)	Asteroid Eros when it is simultaneously at perihelion and in opposition	13·84 million miles

Note.— Such an approach occurs at intervals of about 38 years. An asteroid or a planet is said to be at perihelion, when it comes nearest to the sun, and in opposition when that body, the earth and the sun lie nearly in a straight line, the earth coming between. An interior planet, *i.e.*, a planet whose orbit lies within the orbit of the earth, like Mercury and Venus, can however never come into opposition.

(10)	Asteroid Albert at favourable perihelion	18 million miles
(11)	Nearest Distance of Interior Planet Venus—*Shukra* in Hindu Astronomy	26 million miles

Note

Such a near approach occurs at the time of inferior conjunction, *i.e.*, when the planet comes between the earth and the sun.

Venus is the brightest of the planets, owing to its exceptional power of reflecting the light it receives from the sun. In brilliance it surpasses all the heavenly bodies except the sun and the moon. Being an interior or inferior planet, Venus goes through the whole cycle of phases exhibited by the moon, but the configurations of its phases differ. It appears from the earth as a thin silvery crescent, and as the crescent forms part of a circle six times larger than when the planet is full, it appears brightest in the crescent phase. When

near the height of its splendour, it can be easily seen in broad daylight with the naked eye. The maximum brilliancy of the planet as the Morning Star (Lucifer or Phosphorus) or as the Evening Star (Vesper or Hesperus), occurs about 36 days before or after its time of inferior conjunction. It is then 6 times as bright as Jupiter, or 15 times more brilliant than Sirius, the brightest star in the heavens.

The diameter of Venus is about 7,700 miles, while that of the earth is 7,927 miles. The planet is thus nearly as large as the earth. Its density is about 0·9 as much as the earth's, and mass 0·81 of that of our globe. Its weight would therefore be about 5 sextillion and 340 quintillion tons. It takes 225 days to make one revolution round the sun. Its rotation-period is still in dispute, though Professor W. H. Pickering has declared from his observations that it is about 68 days.

'The earth-moon system as seen from one of the nearer planets, would have the appearance of a brilliant double star plainly visible to the unaided eye. From Venus, for example, the earth would appear much brighter than this planet ever does to us, while the moon would be as bright as Jupiter. It seems probable that the contrasting blue colour of the earth and the yellowish hue of the moon would add much to the beauty of this spectacle in the skies of Venus.'—*Baker*

	Approximate distance from the Earth
(12) Nearest Distance of External Planet Mars—*Mangala* in Hindu Astronomy	34·6 million miles

Note

The orbits of the principal planets are nearly circular. They are ellipses of small eccentricity, but the path of Mars is markedly eccentric. The result is that the distance of the planet from the earth during its opposition periods is not constant.

External or superior planets do not show the entire cycle of phases that the moon does, though their configurations are similar to the moon's. At conjunctions and oppositions, these planets are full, and in other positions highly gibbous.

Mars comes nearest to the earth at a favourable opposition, *i. e.*, when both the planets are near perihelion. While it is visible to the naked eye at all its oppositions, it is seen at its best at a favourable

opposition, for then it is full and shines as a large disc with a red light, excelling Jupiter in brilliancy. Such a favourable opposition occurs at intervals of 15 to 17 years. After 1909, it occurred in 1924.

The diameter of Mars is 4,215 miles. Its mass is nearly 0·11, *i.e.*, slightly over a tenth of that of the earth, so that its weight would be about 725 quintillion tons. Its rotation-time is 24 hrs. 37 m., and revolution-period 687 days.

Mars is also called in Hindu Astronomy *Kuja* *Bhūmiputra* (son of the earth), and owing to its ruddy lustre, *Lôhitaka* (resembling a ruby in colour).

		Approximate distance from the Earth
(13)	Halley's Comet at perihelion ...	41·5 million m.

Note.—The comet returns to this point once in 76·5 years.

(14)	Mars at average opposition ...	49 million m.
(15)	Nearest Distance of Interior Planet Mercury—*Budha* in Hindu Astronomy	50 million m.

Note

Mercury is the nearest planet to the sun. Its orbit being highly eccentric, there is very considerable difference between its aphelial and perihelial distances. Its orbit is said to be more eccentric than that of any other planet. But if similar figures in respect of the newly discovered planet Pluto be approximately correct, it would put Mercury completely in the shade in so far as concerns orbital eccentricity. Mercury comes nearest to the earth at an inferior conjunction when the former is at aphelion, *i.e.*, at its farthest distance from the sun.

Both Venus and Mercury, at inferior conjunction, rise and set with the sun, and as their unlit hemisphere is then turned towards the earth, the planets are not visible to us. At superior conjunction, *i.e.*, when the sun comes between the earth and the planet, the whole of their illuminated side is turned towards us, but as even then they rise and set with the sun, their light is usually lost in its rays. In other positions, Mercury is visible to the unaided eye as a more or less crescent-shaped body, for some days in autumn as the Morning Star (Apollo, as the ancient astronomers called it) before

sunrise, and occasionally in spring as the Evening Star (Hermes) after sunset, when it is near its maximum elongation from the sun.

The diameter of the planet is 3,100 miles. Its mass is 0·04 of that of the earth. It would thus weigh nearly 264 quintillion tons.

		Approximate distance from the Earth
(16)	Maximum Distance of Mars in opposition—occurring at an opposition when both the planet and the earth are at aphelion	62·9 million m.
(17)	Nearest Distance of the Sun, *i.e.*, on the 1st of January, when the Earth is in perihelion in the course of its revolution	91·5 million m.
(18)	Mean Distance of the Sun ...	93 million m.

Note.— As all the planets including the earth revolve in elliptical orbits with the sun at one of the foci, their distances from the sun vary in the course of their revolution. But the orbits of the Earth and Venus are very nearly circular.

(19)	Farthest Distance of the Sun, *i.e.*, on the 1st of July, when the Earth is in aphelion	94·5 million m.
(20)	Farthest Distance of Mercury—occurring when it is simultaneously at aphelion and superior conjunction	136 million m.
(21)	Farthest Distance of Venus—occurring when simultaneously at perihelion and superior conjunction	160 million m.
(22)	Farthest Distance of Asteroid Eros—occurring when simultaneously in aphelion and conjunction	227 million m.

Note.—An asteroid or an external planet is said to be in conjunction when the sun comes between that body and the earth.

(23)	Farthest Distance of Mars—occurring when simultaneously in aphelion and conjunction	246 million m.
(24)	Nearest Distance of External Planet Jupiter—*Guru* or *Brahaspati* in Hindu Astronomy — occurring when in favourable opposition	367 million m.

Note

Jupiter is visible to the unaided eye as a very brilliant object, but surpassed by Venus, and occasionally by Mars, in brightness. It is easily distinguished from Venus, for the latter is not visible at midnight, while Jupiter can be seen even at midnight.

Jupiter is the largest of the planets, with a diameter of 88,640 miles. As the sizes of spheres vary as the cubes of their diameters, it is thus nearly 1,400 times larger than the earth. Its density, however, is about one-fourth of the earth's. Its mass is only 316·94 times that of our globe. The weight of the planet would thus be a little over 2 septillion tons. It rotation-period is only 9 hrs. 56 m., and it takes 11·86 years to complete one revolution round the sun.

	Approximate distance from the Earth
(25) Farthest Distance at which Halley's Comet has become visible	592 million m.

Note.—It was noticed as a tiny hazy patch when viewed through the telescope.

(26) Farthest Distance of Jupiter—occurring when simultaneously in aphelion and conjunction	600 million m.
(27) Nearest Distance of External Planet Saturn—*Shani* in Hindu Astronomy—occurring when in favourable opposition	745 million m.

Note

Saturn is the second largest planet. It usually appears to the naked eye as a yellowish object, just as bright as a star of the 1st magnitude. Its equatorial diameter is 75,100 miles and polar diameter 67,200 miles. In shape, therefore, it is an ellipsoid. Its density is only about one-eighth of the earth's or 0·69 of that of water, though in size it is over 780 times larger than our globe. Its mass is 95·2 times the earth's, so that its weight would be about 627 sextillion tons.

As a planet's rotation-period is determined by observation of any permanent or longstanding spots, the virtual absence of spots on Saturn's surface makes such determination difficult. Astronomers have however succeeded in tracing a few spots near the planet's

equator, and from these they have calculated its rotation-period to be about 10 hrs. 14 m. Its periodic time is given as 29·5 years.

Owing to its ring system, Saturn is the most beautiful telescopic object in the whole host of heaven. Its rings are not continuous sheets, but consist of a number of objects resembling a swarm of meteors revolving round the planet.

		Approximate distance from the Earth
(28)	Farthest Distance of Saturn—occurring when simultaneously in aphelion and conjunction	1,027 million or 1·027 billion m.
(29)	Nearest Distance of External Planet Uranus—occurring when in favourable opposition	1·609 billion m.

Note

Uranus is barely visible to the unaided eye. Its diameter is 32,000 miles. It is thus nearly 66 times larger than the earth, but its density is only one-fourth of that of our globe. Its mass is 14·6 times the earth's. The weight of the planet would therefore be about 96 sextillion tons. It rotates on its axis in 10 hrs. 42 m., and its revolution-time is a little over 84 years.

Hindus call this planet *Varuṇa.*

(30)	Farthest Distance of Uranus—occurring when simultaneously in aphelion and conjunction	1·951 billion m.
(31)	Nearest Distance of External Planet Neptune—occurring when in favourable opposition	2·669 billion m.

Note

Neptune is invisible to the naked eye. Its diameter is 31,000 miles, so that it is nearly 60 times as large as our globe, but its density is only 0·24 of the earth's. Its mass is 16·9 times that of the earth. It would thus weigh about 111·4 sextillion tons. Neptune's rotation-time is given by some astronomers as 15 hrs. 48 m., but according to Jeans, its rotation-period is unknown. Its revolution-period is 164·8 years.

Approximate distance from the Earth

(32) **Nearest Distance of external Planet Pluto—occurring when in favourable opposition** — 2·708 billion m.

Note

This planet was discovered in 1929 by the Lowell Observatory at Flagstaff, Arizona, U. S. A. Its existence had been suspected for over half a century owing to the discovery of minute perturbations of Uranus, not caused by Neptune but by the gravitational pull of some unknown planet. Among the earlier astronomers who attempted to track it down were Pickering and the late Professor Percival Lowell. Its density has not yet been ascertained with any precision. As for its probable size and mass compared with those of the earth, the latest information we have come across is that contained in an article contributed to *Scientific American* of May 1932 by Dr. H. N. Russell, Director of the Observatory at Princeton University, U. S. A., who says :—

> 'Direct calculations of the perturbations of Uranus and Neptune by Pluto show that the former at least could be detected if the new planet's mass were greater than the earth's. Moreover, the faintness of the planet and the failure of experienced observers to see any perceptible disc with the greatest telescopes, indicate that Pluto must be smaller than the earth, and probably no bigger than Mars; in which case its mass is doubtless correspondingly small. Unless Pluto has a satellite bright enough to be photographed with the great reflectors, it may be a long time before we have any accurate knowledge of its mass.'

Under these circumstances it is at present impossible to calculate the probable weight of Pluto.

(33) **Farthest Distance of Neptune—occurring when simultaneously in aphelion and conjunction** — 2·901 billion m.

(34) **Farthest Distance of Halley's Comet—occurring when simultaneously in aphelion and conjunction** — 3·192 billion m.

Note.—The nearest distance to which this body approaches the sun is 50 million miles, the comet then coming within the orbit of the earth, while its aphelial distance is as great as 3,100 million miles or 62 times greater. The ellipse representing its orbit must therefore be one of extreme elongation or eccentricity.

Approximate distance from the Earth

(35) **Farthest Distance of Pluto—occurring when simultaneously in aphelion and conjunction** — 4·692 billion m.

Note

If Pluto's distances from the sun as announced are approximately correct, then a proportionately larger difference exists between its perihelial and aphelial distances than in the case of any other planet. This must be due to the extraordinary eccentricity of its orbit. There would consequently be times when Pluto follows a course within the orbit of its nearest planetary neighbour, Neptune, after crossing its path.

It was announced some time ago that a photographic plate taken by the Canadian Observatory at Ottawa in 1924 revealed, when scanned 6 years later, the existence of a heavenly body beyond Neptune and that Shapley had given the weight of his authority to the announcement that this body was another trans-Neptunian planet. Now comes the report that Pickering claims to have definitely discovered this other planet which he has for the present named 'Planet P'. Its existence is said to have been first indicated by the 'wobbling' of Uranus. Pickering describes it as a gigantic world with a diameter 5 times that of the earth and revolving round the sun at a distance of perhaps 9 billion miles, and says that its year is 656 terrestrial years in length. But Sir Frank Dyson, the Astronomer Royal, is cautious on the subject of this reported discovery, and remarks that he would be inclined to be sceptical if Pickering has based his conclusions on the perturbations of Uranus. Until, therefore, the existence of a tenth planet beyond Pluto is finally confirmed, we must look upon the latter as the outpost of the solar system.

CHAPTER XI

The Moon

O moon! the oldest shades 'mong oldest trees
Feel palpitations when thou lookest in:
O moon! old boughs lisp forth a holier din
The while they feel thine airy fellowship.
Thou dost bless everywhere, with silver lip
Kissing dead things to life. The sleeping kine,
Couched in thy brightness, dream of fields divine:
Innumerable mountains rise, and rise,
Ambitious for the hallowing of thine eyes;
And yet thy benediction passeth not
One obscure hiding-place, one little spot
Where pleasure may be sent. . . .
. . . .
The monstrous sea is thine—the myriad sea!
O Moon! far spooming Ocean bows to thee.

—*Keats*

The most important theory of the origin of the moon is that it was formed by a huge fragment wrenched off from the earth more then a billion years ago. It is believed that our planet, when born, was a perfect sphere of gas. This gaseous ball was spinning so rapidly that it first took the shape of a spheroid and then of an egg. As the oval mass cooled and condensed into a liquid, it began to spin with even greater rapidity than before until it assumed the form of a pear. 'The stalk of the pear developed a bulb, and the waist of the stalk became thinner and thinner.' The day was now only three hours long. 'Tides raised by the sun aided centrifugal force in distorting the earth.' The liquid pear, which had been covered by this time with a crust 35 miles thick, could not resist this combined onslaught. The stream of matter that formed the bulb was suddenly torn off. In this great planetary catastrophe our satellite was born. Some astronomers hold to another theory, *viz.*, that the basin now filled by the Pacific Ocean supplied the

material that went to form the moon. This theory is refuted on the ground that the Pacific basin is only 1/30th as large as the moon and that a quantity of material enough to fill even three oceans—the Pacific, Atlantic and Indian—would not suffice to make up a moon.

Of all the heavenly bodies, the moon, to us on the earth, is second only to the sun in importance and interest. It is the nearest to us of all the celestial objects. Its apparent big size is due to its very small distance from us, compared with the distances of the sun, the planets and the stars. It is spherical in shape and is one of the smallest bodies visible in the heavens. The moon's diameter is about 2,160 miles, so that its volume is only about 1/49th of that of the earth. Its density is about 0·6 as much as the earth's, as the moon is composed of relatively lighter materials. Its mass is 1/81·56 of that of our globe. The weight of the moon is thus 80 quintillion tons, or *58 times the weight of all our oceans.*

Like the sun and the planets, the moon also rotates on its axis. It is the earth's sole and faithful satellite and revolves round it in an elliptical orbit in about 27⅓ days. This period is called a *sidereal month.* The same also is the moon's rotation-period. One result of its revolution is that the moon changes its appearance from day to day in the course of a month. These changes, as seen by us, are called Phases of the Moon. The interval of time between two phases of the same kind, *e.g.*, between one full moon and the next, is known as a *synodic* or *lunar month.* Its length is slightly more than 29½ days.

The moon is not a self-luminous body. It is a dark sphere like our own globe. It shines solely by reflected sunlight, and accordingly only one half of it is lit up at a time. In the course of its revolution, its illuminated hemisphere is presented to us in varying proportions. Thus it is that we sometimes see a crescent, sometimes a half, sometimes a gibbous moon, and at other times a full moon. When the moon is in conjunction, *i.e.*, comes between the earth and the sun, its lit-up side is completely turned away

from us, and we then have dark nights. This phase is called New Moon.

The moon always turns the same side towards us. We therefore never obtain a view of its other hemisphere. This is due to the circumstance that it takes exactly the same time to go once round on its own axis as it does to complete one revolution round the earth.

Examination through a telescope shows the lunar surface to be extremely rugged. The moon's details have been closely studied with the help of this instrument and have even been mapped. Its surface is strewn with craters, mountain chains, plains, rills or clefts, and 'rays', many of which have been given names for identification.

The *craters* are conspicuous ring-like objects scattered over the moon's surface in profusion. They are believed to be its extinct volcanoes. The smallest of them, or craterlets, are 1,000 feet across or less, but some are of enormous size, the largest measuring as much as 150 miles in diameter, and are surrounded by lofty walls like crenellated ramparts rising to a maximum height of 24,000 ft. They have thus the appearance of vast amphitheatres. The total number of craters of all sizes has been estimated at upwards of 30,000.

The mountain ranges are few in number. The most prominent of them are called Apennines, about 450 miles long, the highest being the Leibnitz and the Doerfel. Near the south pole of the last two ranges and almost beyond the moon's limb, there are peaks with elevations of 26,000 ft. Sir Robert Ball says that the highest peak of the Leibnitz has been found to be more than 41,900 ft. above a neighbouring valley. By way of comment he adds that, in comparing the heights of lunar mountains with those of terrestrial ones, in the latter case the depth of the ocean must be added to the elevations of the peaks, and that, calculated on this basis, the highest mountains on the earth will be found to be higher than any known in the lunar world. Yet in proportion to the size of the moon, it

can be said that the lunar mountains are much loftier than those of the earth.

The dark patches covering part of the moon's surface and so conspicuous at an ordinary full moon, represent the plains. They were believed to be seas by astronomers before the invention of the telescope. The number of such 'seas' is 14, and though they are really deserts often covered with craterlets and rocks, their names—*Mare Foecunditatis, Mare Serenetatis* etc.— are still retained. The largest is *Mare Ibrium*, which is a little over 700 miles across.

Rills or *clefts* are deep, narrow, irregular chasms, about half a mile across, between parallel ridges or elevated portions. More than 1,000 such abysses have been discovered.

Rays are a system of bright streaks, with a maximum width of 10 miles, which radiate from the vicinities of some of the craters and generally traverse mountain and valley. At full moon, Copernicus, one of the grandest and best known of the craters, is seen surrounded by these streaks.

In the course of its revolution round the earth the moon comes in opposition from time to time, so that the earth finds itself between the sun and the moon. Our satellite sometimes passes then through the earth's shadow and is obscured. It is then said to be eclipsed. Lunar eclipses occur only when the moon comes in opposition at a full phase. They may be either partial or total and are visible wherever the moon is above the horizon at the time. They are thus observable over more than half of the earth, taking into account that portion of it which, during the earth's rotation, keeps the moon into view. A total eclipse may last as long as four hours.

A peculiar phenomenon noticeable in clear weather at a total lunar eclipse is that, in spite of its surface being darkened, the moon sends forth a faint reddish light. Sunlight traversing our atmosphere near the edge of the earth is refracted into its central dark shadow, and the enfeebled beams impart to the moon a dull light of coppery hue. Occasionally the parts of the moon's disc near the edge of the shadow show a bluish-grey tint. A lunar eclipse furni-

shes one more proof that the earth is round, for the earth's shadow falling on the moon is seen to have a circular outline. But the phenomena accompanying lunar eclipses are of little astrophysical interest to-day unlike those attending eclipses of the sun.

The moon's gravitational pull is only $\frac{1}{6}$ of that of the earth. Thus a body falling at the earth's surface 16 feet for the first second would fall only 2 ft. 8 inches for the first second on the moon. A man weighing 125 lbs. on the earth would weigh only 21 lbs. in the lunar world in a spring-balance. He would not very much mind a jump from a height of 42 ft. there, for it would mean to him no more than a 7-ft. jump from a wall on the earth, and it would take him six times longer to reach the ground. Similarly, a leap from the ground there would take him 18ft. high, while he would only rise a yard on the earth.

The moon, by its power of attraction, causes the daily ebb and flow of the tide — the scavenger of our seacoasts.

We reserve a description of the extraordinary physical conditions on the moon and of the lunar 'skyscape', for a later chapter.

CHAPTER XII

The Sun

> Oh! what pencil of a living star
> Could paint that gorgeous car,
> In which as in an arc supremely bright,
> The Lord of boundless light
> Ascending calm o'er the Empyream sails,
> And with ten thousand beams his beauty veils.
>
> —*Hymn to the Sun : Translated by Sir William Jones*

> Yonder comes the powerful king of day,
> Rejoicing in the east. The lessening cloud,
> The kindling azure, and the mountain's brow,
> Illumed with fluid gold, his near approach
> Betoken glad. Lo! now apparent all,
> Aslant the dew-bright earth and coloured air,
> He looks in boundless majesty abroad;
> And sheds the shining day, that burnished plays
> On rocks, and hills, and towers, and wandering streams,
> High-gleaming from afar. Prime cheerer, Light!
> Of all material beings first, and best!
> Efflux divine! Nature's resplendent robe!
> Without whose vesting beauty all were wrapt
> In unessential gloom; and thou, O Sun!
> Soul of surrounding worlds! in whom best seen
> Shines out thy Maker! may I sing of thee?
>
> —*Thomson*

The sun is the great dispenser of light and heat to the earth and the other planets. Little wonder, therefore, that it was worshipped by the ancients as the visible emblem of divine power and glory.

The sun's diameter is about 866,000 miles, and as the mean diameter of our globe is 7,918 miles, the sun is about 1,300,000 times larger than the earth. It is about 750 times larger than all the planets put together.

Our luminary is an immense globe of white-hot vapours. Its surface temperature is estimated at between 6,000° and

8,000° C., and central temperature at 40 million deg. C. This central heat, says Jeans, is so fierce that oxygen atoms would break up in it, so that no atoms of this element could exist at the sun's centre except only as a promiscuous flock of nuclei and electrons flying about helter-skelter. But terrific as this heat is, it is not sufficiently powerful to completely break up other types of atoms. While these latter are losing their outer electrons, their nuclei are holding the innermost electrons in so tight a grip that even so terrific a temperature as 40 million deg.C. is too weak to dislodge them.

Until recently it was assumed that the temperature at the solar surface was uniform throughout, but according to a new theory advanced by Professor Albert Einstein, the solar body is cooler at the equator than at the poles. Einstein believes the movement of the atmosphere over the sun's surface to be due to the inequality of temperature between its poles and its equator. This difference is accounted for by a more active radiation along the equator than at the poles, which makes the surface less hot at the equator. The sun's heat is so intense and its light so dazzling that great care is taken in viewing this body through a telescope. A special eye-piece with a suitable dark glass is used as a protection for the eyes.

The total number of known elements is 92, of which 90 are found on the earth. The solar spectrum has shown that in the sun's atmosphere 61 elements are represented with varying degrees of probability, all in a gaseous or vaporous state. Chief among these are hydrogen, helium, oxygen, nitrogen, carbon, sulphur, sodium, potassium, calcium, cobalt, nickel, iron, copper, zinc, tin, lead, aluminium, magnesium, manganese, silver, chromium and strontium. Oxyen, nitrogen, carbon and sulphur exist in the atomic state, and a large proportion of the metals occur in the neutral as well as ionized states. If the tidal theory of the origin of the solar system—which we find has been attacked in recent months by a few scientists—is correct, all the other elements found on the earth which

have not been so far traced on the sun must be present in its interior.

The bright visible exterior of the sun is called the *Photosphere.* It is this part—a relatively thin layer of intensely hot, cloud-like, condensed vapours—which sends forth all the heat and light received by the planets. It was for centuries believed that the sun had a pure and spotless surface, but in 1610 Galileo, the great Italian astronomer, discovered through his telescope, for the first time, dark spots on it. These are called *Sunspots.* They are immense volcanoes which, according to one theory, are produced by gigantic whirlpools or vortices set up between the great moving layers of superheated, glowing gases within the sun, 'each a spiralling funnel moving at incredible velocity, spurting up clouds of hydrogen, calcium and other elements, sucking the fiery vapours back into its capacious crater where atoms are smashed, stripped, excited into intense radiation and bombarded into space.' Thus every sunspot that crosses the face of the sun pelts the earth and the other planets with a hail of these electrical missiles. It has been found from observations extending over more than two centuries that the number of auroral displays over the earth closely follows the number of spots on the sun. This is the most important datum on which many scientists base their view that aurorae are caused by this bombardment from the sun. It is this bombardment, again, which in their view produces such terrestrial changes as cold waves, droughts, floods and those atmospheric disturbances known as magnetic storms which are frequently accompanied by earth currents of electricity, sometimes powerful enough to seriously interfere with the working of the telegraph and telephone lines and submarine cables. They also believe that it is the collision of these high-speed ionized particles ejected from the sun, with the atoms of of our upper air, that is responsible also for the radio difficulties which recur with the increase of sunspots. The activity of a sunspot continues until the internal pressure is relieved. It is 'as though the sun had occasional stomach-

aches caused by the formation of gas.' With the subsidence of the pressure to a point which is less than the weight of the outside layer of the sun, the crater closes up.

Sunspots are mainly found in two zones on each side of the solar equator, but rarely in latitudes higher than 35°. Their dimensions vary considerably. Some are very small. They are sometimes so enormous in size that they are frequently visible to the naked eye at sunset, and at other parts of the day can be observed through a smoked glass or a piece of densely fogged photographic film. They often appear in clusters, and a large spot is often attended by several smaller ones. One large group of spots observed in February 1892 was found to be about 150,000 miles long and 75,000 miles broad, thus covering an area of about 11 billion sq. miles on the face of the sun! Another vast procession was observed in October or November 1929, which, according to report, extended along the solar disc over a phenomenal length of 700,000 miles, *i.e.*, more than four-fifths of the sun's diameter! One other remarkable factor about this unusual outburst was that it had been predicted by Dr. Stetson ten or eleven months prior to the occurrence, with such data as previous sunspot records afforded as to their periodicity. A giant spot observed on 10th March 1929 is reported to have been about 1·5 billion sq. miles in area.

Telescopic examination of the larger sunspots has shown that they usually consist of a central, apparently dark nucleus called the *umbra*, surrounded by a lighter margin called the *penumbra*. The penumbra is seen as a dense ring of filaments, looking like blades of straw, radiating towards and usually curving in the direction of the spot-centre. Both the umbra and the penumbra are in fact exceedingly luminous, but appear dark only by contrast with their much brighter photospheric envelope.

The average duration of sunspots is three to four weeks, though one spot lasted 18 months in 1840-41. The smaller ones often disappear within a few days, in some cases within a few hours. Sunspots wax and wane in

cycles, the average interval between successive maxima in number and size being 11 years and 4 months. The distribution in latitude of the spots also shows a periodic change during the sunspot cycle.

An important discovery was made in 1909 at the Solar Physics Observatory at Kodaikanal (India) regarding the structure of sunspots. It is since known as the 'Evershed Effect'. Mr. John Evershed showed that in the penumbrae of spots the metallic vapours indicate a radial movement outward from each spot-centre, the velocity of movement amounting to over 2 km. per second at the outer limits of the penumbrae. He also showed that in the higher Chromosphere, a region of the sun's atmosphere described below, ionized calcium and hydrogen vapours show an inward radial movement towards the spot-centre, the velocity of this flow being about 1·5 km. a second.

In the vicinity of sunspots are frequently seen brilliant streaks or patches called *faculae*, a Latin term meaning 'little torches'. They are most clearly observed when they come to the limb or circumference of the sun, as the solar disc is less bright at the edges than at the centre.

The lowest layer of the sun's atmosphere, which lies immediately above the Photosphere, is called the *Reversing Layer*. It is a few hundred kilometres in thickness and contains all the elements found in the solar atmosphere.

At ordinary times the less luminous appendages of the solar disc are not visible. These wonderful phenomena become visible at a total eclipse of the sun, an occurrence briefly dealt with later. The solar envelopes then to be seen are:—

(1) The *Chromosphere*, which is the upper stratum of the solar atmosphere, extending immediately above the Reversing Layer. It is so called owing to the coloured lines shown in its spectrum. It is a brilliant and tumultuous sea of scarlet flame, 7,500 to 8,750 miles in height, consisting of permanent, incandescent, non-condensable gases and vapours of extreme tenuity, though it is less luminous than

the Photosphere. It contains most of the elements present in the sun.

(2) *Prominences* or *Protuberances*. These are vast masses of the vapours of the Chromosphere, usually of crimson colour, which are tossed from time to time from the luminous surface of the sun to heights of 100,000 miles or more. Their red colour is due to the glowing hydrogen. They often assume fantastic shapes as they rise. Since the invention of the spectroscope in 1868 a method has been devised to observe them by means of this instrument even in the absence of a solar eclipse, and since then they have been systematically studied. They are now photographed with the spectroheliograph on every clear day.

Prominences are of two kinds, quiescent and eruptive. The former are of huge size, but are faint and remain unchanged above the solar surface like clouds for days together. They occur at all parts of the sun's limb. They are composed mainly of hydrogen and helium and vapours of calcium. The eruptive prominences are brighter, more active and subject to rapid changes. Besides hydrogen, helium and calcium, their discharges contain sodium, iron, magnesium and other metals. They frequently leap up as narrow tongues of flame with enormous velocity. At a total eclipse of the sun they add to the spectacular grandeur of the phenomenon. Unlike the non-eruptive prominences, they appear only in the sunspot zones. They have the same periods of maximum and minimum activity as the spots, *viz.*, 11 years and 4 months.

Professor Young gives an account of a remarkable prominence seen on 7th October 1880 at about 10-30 a. m. It was at that moment about 40,000 miles high. Half an hour later it became very brilliant and doubled its height. For another hour the mighty flame soared upward until it attained the great height of 350,000 miles. At this point it seemed to have exhausted its energy, for it broke up into fragments, and within two hours of its first appearance the phenomenon had completely faded away. Its vertical speed

was thus 43 miles a second. *The Sphere* of 25th June 1927 contains a reference to eruptive prominences observed which shot up to a height of 500,000 miles at a speed of 300 miles per second or over a million miles an hour! But even this height record has since been broken by a prominence photographed at intervals during its rapid rise, at the Kodaikanal Observatory, on 19th November 1928. It had reached a height of 567,000 miles, a value nearly two-thirds of the sun's diameter, when clouds unfortunately intervened. The greatest velocity attained by this prominence was 143 miles a second.

Incidentally it may be mentioned that it was at this observatory that a shift in the lines of the solar spectrum towards the red end, in accordance with the values predicted by Einstein's Theory of Relativity, was first observed in 1914 by Evershed and Dr. Royds, and confirmation was thus obtained of this part of the theory.

(3) The *Corona* or Aureole of Light, which is a picturesque filmy halo of complex structure around the limb of the sun. It is brightest near the sun but fades away into faint but enormously long streamers which, according to Abbot, shoot up to heights commonly of 2·5 to 3·5 million miles, the greatest height recorded being about 8·5 million miles. The streamers at the solar poles are shorter and of a characteristically curved shape. The corona is the outermost solar envelope and is seen as a luminous circle of pearly colour surrounding the black body of the moon at a total eclipse of the sun. It is like moonlight streaming from behind a charred and absolutely lightless moon! At such times the corona is one of the grandest of natural phenomena. Eclipse observations during the last half-century have shown that it shines partly by its own light but mostly by reflected sunlight. It is exceedingly tenuous and would appear to be composed partly of cosmic dust and partly of gaseous matter.

We know that, when the moon in the course of its revolution round the earth comes between the sun and our planet in such a position that the centres of the three bodies,

if joined, would form a straight line, and the moon's shadow fully reaches the earth, the result is a total eclipse of the sun. This shadow sweeps across the earth's surface with great swiftness from west to east. The totality therefore is generally of a few minutes' duration, the maxmium recorded being only 7 minutes 40 seconds, and the minimum barely 2 seconds. The next total eclipse of the sun expected to be visible in India is predicted to occur on 20th June 1955, when the regions swept by the shadow will be Ceylon, Siam and the Philippines. According to calculations, it will last fully 7 minutes.

A total eclipse of the sun is a rare sight at any particular station. As a spectacle, it ranks among the most sublime and awe-inspiring of celestial phenomena. The astronomer Howe gives a most impressive description of it and of the remarkable phenomena which accompany it :—

'Just before the sun is entirely covered, the landscape assumes an unearthly hue. Awe seizes the beholder; one sometimes sees the moon's shadow advancing through the air with terrifying swiftness as if to smite him. In a few seconds it reaches him, and the last ray of sunlight is gone; the planets and bright stars appear. Around the black ball now hanging in the sky, the pearly corona flashes out in all its weird beauty. At its base glow the prominences, like rubies set in pearl. Men's faces grow ghastly. The silence of death is upon the beholders. Soon there is a sudden flash of sunlight at the western limb of the moon; the corona and the prominences fade apace. The gloom is overpast, and silence gives place to exclamations of wonder and delight.'

If such is the impression a solar total eclipse makes upon man, what is its effect on animals? Let us quote the answer:

'Bees return to the hive. Chickens go to roost. Caged birds put their heads under their wings. Bats and owls fly out of their accustomed retreats. Dogs are terrified, and sometimes howl dismally. Horses have been known to lie down in the public highway and refuse to advance. Some oxen were once

to range themselves in a circle back to back, with horns outward, as if to resist an attack.'

Another interesting phenomenon usually attendant on a total eclipse of the sun is that known as Baily's Beads—named after the English astronomer, Francis Baily, who first noticed them during a solar eclipse. They present an appearance somewhat similar to a string of beads. They are the last glimpses we have of the solar disc just before the commencement of totality and are also the first glimpse of that disc after the totality is over. The effect lasts for 15 seconds each time and is caused by the breaking up of the narrow crescent of sunlight in several places owing to the rugged, mountainous character of the moon's surface. A single bead produces what is called the diamond-ring effect.

The area darkened by the moon's shadow on the earth at a total eclipse of the sun is only about 167 miles in diameter. With the advent of the aeroplane it struck a scientist to attempt to take an aerial photograph of this shadow on the earth at a solar eclipse, and Dr. Jeffreys succeeded in doing so for the first time from a height of 10,000 feet.

During a total eclipse of the sun when the earth is passing through the full phase and the moon is new, an observer on the moon would see its tapering shadow sweep across the illuminated disc of the earth as a small black spot surrounded by a lighter circular shadow whose edges are not clearly defined.

In a paper read before the Société Française de Physique, Mons. Bernard Lyot of the Meudon Observatory near Paris announced an achievement of high importance, the result of a series of observations made by him on the summit of Pic du Midi (9,466 ft.), a peak of the Pyrenees in Southern France, in the summer of 1931. He succeeded in obtaining observations of the light of the corona without the aid of a total eclipse. Using a faultless telescopic objective and stopping it down to an aperture of 4 centimetres (1·575 inches) in diameter, he placed in the focal plane a blackened disc whose radius reached an angular distance of ·30 seconds (= 2·5 inches in the duodecimal

system) beyond the radius of the sun's image. Another lens placed behind the disc produced an image of the first lens on a diaphragm, and the hole in the centre of the diaphragm was covered by a small opaque screen. The edge of the diaphragm intercepted the light diffracted by the edges of the first lens, and the screen cut off the light of the sun's image formed by the internal reflection from the faces of that lens. A well-corrected objective placed behind the diaphragm and the screen produced an image of the corona. On examination of this image with an eye-piece, the prominences could be seen round the limb of the sun with a rose-red colour. In particularly favourable conditions of weather, the corona could be photographed by means of a red filter.

In an article in the French journal, *L'Astronomie*, for June 1932, Lyot states that the brightness of the inner corona is nearly equal to that of the planet Mars, which is easily seen in daytime.

One of the greatest obstacles to observation of the corona under ordinary conditions is the presence of particles of dust in the air and the diffusion of sunlight caused by the gas molecules in the atmosphere. The higher levels of the Western Himalayan peaks are noted for the clearness of the air. Were an instrument of the kind used by Lyot installed at a convenient elevation here, it ought to be possible to obtain results still better than those secured by him.

At the Faraday Centenary celebration in London in 1931 Professor Elihu Thomson predicted that television would some day make it possible for the whole world to see a total eclipse of the sun in whichever part of the earth it occurred. Mr. O. H. Caldwell of New York gave an ingenious and impressive demonstration on 24th November 1931 at the American Museum of Natural History, in which he showed what could be done even with present methods to televise a solar eclipse. Since no eclipse was available at the moment, a drawing of the sun speckled with sunspots was gradually observed through a slightly smaller disc

representing the moon. The result was an approach to an annular eclipse. As the corona cannot be produced artificially, something resembling it was produced to enable the assembled engineers to judge what could be shown on televising screens when the next eclipse became visible in that part of America.

In recent years, at total solar eclipses astronomers were occupied with the photography of stars close to the sun in order to ascertain whether their light is deflected in the sun's gravitational field according to Einstein's theory. At the West African eclipse of 1919 they obtained photographs on which a deflection was clearly shown, and this deflection was of the amount predicted by the Theory of Relativity.

A hazy conical band of light known as the *zodiacal light* is observed in spring stretching upward from the point in the horizon where the sun has set. A similar spectacle may be seen before sunrise in autumn. This phenomenon is usually ascribed to light reflected from a lens-shaped cloud composed of solid particles, presumably a swarm of meteors lying in intra-Mercurial space, too small to be seen individually and revolving round the sun just as the rings of Saturn do around that planet.

The magic colours normally displayed at sunset, varying from a clear bright white to orange and crimson, are due to the scattering of light by the minute gas molecules of the air. Certain subterranean forces too of our world indirectly enhance the beauty of the rising and setting sun, though this happens on extremely rare occasions. The sky at sunset becomes at such times, to use the words of Ruskin, 'one molten mantling sea of colour and fire'. The unusual sunset glows due to the clouds of volcanic dust spreading over the earth at the great outburst of Krakatoa described in Chapter IV, were so imposing in their splendour as to stir Tennyson to refer to the phenomenon in impressive verse:—

'Had the fierce ashes of some fiery peak
Been hurled so high they ranged round the world,
For day by day through many a blood-red eve
The wrathful sunset glared.'

Under Item 1 of Chapter IX we have given a brief explanation of the rainbow. It is one of the most beautiful and familiar optical phenomena relating to sunlight. For the production of a rainbow three conditions have to be fulfilled: first, rain must be falling near the observer in the direction opposite to the sun; secondly, the sun should not be hidden by clouds; and thirdly, it should not be too high in the heavens. The centre of the rainbow arch lies on the prolongation of a straight line drawn from the sun to the observer's eye. The bow attains the greatest length when the sun is at the horizon, for it will then appear as a huge semicircular arch opposite to the sun if a shower is falling in that direction. If the sun is far above the horizon, the bow will be seen as an arc smaller than a semicircumference. The brilliance and colouring of a rainbow are governed to a large extent by the size of the drops in the rain. It has been calculated that, in order to produce a bow displaying the whole range of spectrum colours, the raindrops must be more than 1/25th of an inch in diameter. When they are smaller, the outer edge of the bow is coloured orange, for then the red end of the spectrum disappears. When perfect, the rainbow presents the appearance of two concentric arches, the inner principal one being called the *primary* and the outer, generally a fainter one, the *seconddary* bow. Each of the bows is formed of the colours of the solar spectrum, but the colours are arranged in the reversed order, the red forming the exterior ring of the primary bow and the interior of the secondary. The secondary bow is caused by the sun's rays entering the under part of the raindrops. Sometimes are seen lying close inside the violet of the primary bow or outside that of the secondary what are called *supernumerary* or *spurious* bows. These are of a pinkish colour and are formed by the scattering or diffraction of light by tiny drops of rain. On such occasions the region of the sky outside the principal bow is per-

ceptibly brighter than the region within the arch. The sky outside the secondary bow is somewhat brighter than in the region between the primary and secondary bows.

Sunlight is also responsible for the artificial rainbow produced by the spray from a geyser, a cascade or a garden fountain. Still another kind of bow caused by the sun is the *fog-bow,* which is seen under favourable conditions when the sun shines from behind an observer on to a fog-bank. Owing to the droplets in a fog being exceedingly small, very little colour is noticeable in a fog-bow, all that is discernible being a bluish tinge on the inner edge and a reddish tinge on the outer edge. It is frequently seen from the top of a hill, and the observer may notice his own shadow on the fog-bank with a halo of coloured rings around the head. The phenomenon is known as the *Brocken Spectre.*

The light emitted by the sun, says Jeans, is of 3·23 octillion candle-power! It radiates its light and heat in profusion in all directions, the earth intercepting but an infinitesimal fraction, less than one 2-billionths, of this radiation. In fact, according to the 5th Revision of the Meteorological Tables of the Smithsonian Institution of Washington, at the surface of the earth the noon-day sun on a clear day has an intensity of only 9,600 'foot-candles', a foot-candle denoting the illumination received from a standard candle placed a foot away. Starlight amounts to only 1/8000th of a foot-candle, and the sun is 120 million times brighter than all the stars in the sky on a fine night. By way of a comparative estimate of the brightness of the sun and of the full moon, Baker says that something like 465,000 full moons at average distance would be required to produce a brilliancy equal to the sun's. He adds that in the visible half of the celestial dome, there is room for only a fifth of this number. Visible sunlight carries about 19 per cent of the energy from the sun. The ultra-violet rays contain only 1 per cent and the infra-red about 80 per cent of its radiant energy.

The sun is an enormous power plant. It is estimated that the amount of heat generated by it every second has a mechanical equivalent of 20 trillion horse-power !

Though a relatively small fraction of the solar radiation reaches our globe, even this portion of the total varies, and as a result we experience summer or winter with its roasting heat or biting cold. Under the influence of this radiation the water on the earth evaporates, and clouds, fogs and rain are formed. It instils energy into the earth's atmosphere and produces winds—the gentle zephyrs of spring as well as whirlwinds, hurricanes and other winds of destructive power. The coal, oil and gas so widely used over the world owe their origin to solar energy. The gracious beams of the sun enable the vegetable cell to function like a chemical laboratory, and plants to absorb water-vapour from the atmosphere and decompose the poisonous carbonic acid gas of the air into its elements, carbon and oxygen. The carbon is taken up by the plants as food, while the oxygen goes to sustain animal life. The sun's rays are thus essential for the sustenance of both vegetable and animal life on the earth. It is the sun's radiation, again, that clothes the leaves of plants in green and yellow and robes the flowers in their gorgeous hues. All vegetation has the property of absorbing the sun's rays falling on it and extracting from them one or more of the colours of which sunlight is composed. For the bounty of Nature, for the radiant smiles and manifold charms with which she greets us in many parts of the world, we are indebted primarily, of the myriads of bodies that tenant the vast ocean of space, to our peerless luminary.

> 'Like a God thou art, and on thy way
> Of glory sheddest, with benignant ray,
> Beauty and life and joyance from above.'

The gravitational pull of the sun on bodies at its surface is as great as 27·6 times the attractive force of the earth on objects at *its* surface. A freely falling body on the earth drops for the first second 16 feet, while on the sun it would fall 441 feet for the first second. A man

weighing 125 lbs. on the earth would weigh on the sun over a ton and a half in a spring-balance! By its powerful gravitational force the sun keeps the planets and other members of the solar system in their respective orbits 'as with a chain indissoluble bound', making them revolve round it. But for this supreme control, the system would immediately disintegrate and its members would dash out into space in straight courses. The sun is thus the ruler of the whole system.

The average density of the sun is about one-fourth of that of the earth, as its material is relatively lighter. It thus amounts to about one and a half times that of a globe of water of equal size. But the mass of the sun is immensely greater than the earth's. It is measured by the force of the sun's gravitational attraction on a planet. The distance of a planet from the sun being known as well as the speed of its orbital motion, the astronomer has been able to calculate the distance which the planet is attracted towards the sun in one second. He has in this way found out how many times the sun should be heavier than the planet to be able to exert this amount of gravitational pull. The mass of the sun has thus been ascertained to be 331,950 times that of the earth. At the end of Chapter I we have given two results arrived at as the earth's weight, the difference between them being comparatively small. On the basis of the higher of these values we find that the weight of our luminary works out to 6·593 sextillion tons × 331,950 = 2,188,547,000,000,000,000,000,000,000 or in round figures 2 octillion tons! This result is easily verified. The sun's volume is 340 quadrillion cubic miles and density about ¼ of that of the earth. We know the earth's volume to be 260 billion c. miles and weight 6·593 sextillion tons. Now if a sphere with a volume of 260 billion c. miles and a density of 1 weighs 6·593 sextillion tons, a sphere whose volume is 340 quadrillion c. miles and density ¼, will weigh

$$6{\cdot}593 \times 10^{21} \times \tfrac{1}{4} \times \frac{34 \times 10^{16}}{26 \times 10^{10}} = \text{slightly less than 2 octillion tons.}$$

The nominal difference is due to our having taken only the

approximate values for the sun's diameter and density. The sun is over 750 times as heavy as all the other members of the solar system put together—the planets and their satellites, the asteroids or minor planets, and the comets.

The pressure at the surface of the Photosphere is only 1/1000th of an atmosphere, whereas the pressure at the sun's centre is terrific and is estimated at 36 billion atmospheres, which works out to slightly over 236 million tons to the square inch or more than 10,500 times the pressure at the centre of the earth!

So profusely is the sun pouring out its energy into space that it is estimated as losing mass at the staggering rate of 4,200,000 tons a second. This loss works out to nearly 363 billion tons a day or over 132 trillion tons a year! It is estimated further that the sun has been radiating away its mass for about 7½ billion years, a value which represents its present age. But even if it is destroying its atoms at this enormous rate from day to day and from year to year, its present stock of atoms, considering the stupendous weight of our luminary, is large enough to last more than 16 trillion years from to-day!

CHAPTER XIII

The Dreams of Rocket Science

O Nature! all-sufficient! over all!
Enrich me with the knowledge of thy works;
Snatch me to Heaven; thy rolling wonders there,
World beyond world, in infinite extent,
Profusely scattered o'er the blue immense,
Show me. —*Thomson*

Great experiments are being carried out, especially in Germany, France, Russia and America, to develop rocket aeroplanes, both unmanned and man-carrying, capable of reaching and flying far out in the upper atmosphere.

Professor Hermann Oberth, the German scientist, suggests the use of two rockets, one containing alcohol and the other hydrogen. In the view of some scientists the hydrogen can be used to regenerate the alcohol after the latter has been used up to propel the rocket 'plane, but German experimenters generally use liquid oxygen and liquid hydrogen, which are brought together through separate pipes and ignited. A liquid fuel developed by Dr. Paul Heylandt, a German expert on liquid gases, which may or may not be this oxygen-*cum*-hydrogen, has been hailed as a revolutionary contribution to rocket science.

Professor R. H. Goddard of Clark University, U.S.A., who has been experimenting on rockets since 1909, is developing a 'Stratosphere Rocket' which will carry aloft automatic instruments for obtaining weather data from the upper air. He has besides patented a man-carrying rocket-turbine aeroplane. It is a machine which combines the principles of both the rocket and the turbine. In leaving the earth the rocket blast of the 'plane is directed through the heat-resisting metal blades of two turbine wheels, the revolutions whereof drive a pair of air-propellers and supply

the machine with the necessary motive power in its flight through the denser layer of the earth's atmosphere. But on reaching the thin upper air, the pilot operates a device whereby the turbine blades are swung out of the path of the exhaust gases of the rocket, and the propellers disconnected. Owing to the much lower air pressure in this rarefied region, the craft is thenceforward propelled by the 'kick-back' of the rocket explosion. The fuel to be used is a mixture of gasolene and liquid oxygen.

Scientists are confident that rocket craft will fly at very high altitudes and at enormous speeds.

The world's rocket enthusiasts are not going to stop with the attainment of their immediate goal, the construction of a man-carrying Stratosphere Rocket equipped with scientific instruments. Their aspirations soar infinitely higher. They have already started Societies for the promotion of research in the new field of 'astronautics'. Prominent among these organizations are the German Society for Interplanetary Navigation, Société d'Astronautique de France and the American Interplanetary Society. An International League of Interplanetary Rocket Inventors and Scientists has been formed and an International Bureau established for furthering rocket research and carrying out experiments for the more rapid development of the 'Interplanetary Rocket'. The Bureau has its head-quarters at Berlin, as Germany is the only country in the world which maintains a 'Rocket Aerodrome', a flying field for rockets. It is situated at Reinickendorf, just outside Berlin.

Dr. Lyon, the American expert who has established the world's altitude record for sounding rockets (*vide* Chapter VI, Item 3), is said to be on the eve of perfecting at Vienna an explosive powerful enough to blow up a town with a single bomb and about twice as powerful as TNT (trinitrotoluene), the most violent explosive employed in the Great War. This new substance is known as T. 4, its full name being Trimethylentrinitramine, and though known to science for many years, it has never been used as

an explosive owing to its being non-fusible unlike TNT. German and Italian scientists have failed in their experiments to make it fusible, but Lyon claims to have succeeded in doing so, and by combining it with other explosives, obtained a speed of exhaust that will enable a rocket to travel at a velocity of 2 miles a second, a speed considerably higher than that attained by any means hitherto. Rockets built on present principles consume so large an amount of explosive in their journeys into the air that they come back to earth after going up a few miles. By using an explosive that will last longer and enable the rocket to continually propel itself by the driving power of its own exhaust, Lyon expects to be able to 'cut the bands of gravitation and atmosphere that bind us to the earth.' His rocket for space flight will be constructed on much the same principle as his larger sounding rocket which came to grief in 1931, with the addition of steel fins attached to the lower section, which with the gyroscope will keep the rocket steady during the first stage of the flight. When the fins drop off with the consumption of the lower section, the gyroscope will steer the rocket during the rest of its long voyage, and with the falling off of each section in its turn, the velocity of the rocket will automatically increase. 'The wet blanket of the atmosphere', adds Lyon, 'retards speed in the same way as the sea retards a liner; doubling the speed of a rocket merely quadruples air resistance. There is, however, the consolation that gravity decreases in regular stages as the distance from the earth increases. For instance, a rocket that weighs a ton on earth will weigh only a quarter of a ton when 4,000 miles up, and only the twenty-fifth of a ton at 20,000 miles above sea level.'

In an interesting article in the *Illustrated Weekly of India* of 15th November 1931, Lady Drummond-Hay gives an account of her visit to the German Rocket Aerodrome where she interviewed Professor Rudolf Nebel, the famous rocket expert, under whose direction its activities are carried on. He unfolded to her his romantic plans for the deve-

lopment of rocket transport. He has in view first the construction of a rocket that will 'shoot' mail from Berlin to New York in 25 minutes! Next will follow a powerful rocket in which he himself will fly to Australia in half an hour! The first passenger rocket will be about 75 feet long and will have comfortable accommodation for passengers. It is expected to weigh by itself one ton, but will carry 29 tons of rockets and fuel. Developing half a million horse-power, it will fly 7 miles a second in a curvilinear course and reach a maximum height of 153 miles! Tapping a small 1,360 horse-power rocket, the scientist remarked that from such a little thing would grow the great rocket to Australia and later the Rocket to the Moon!

Nobel feels confident that in less than fifteen years he will have popularized the rocket for carrying mail between Continents and brought passenger-transport by it within the bounds of practicability. The shooting of mail will be the first stage which, in his opinion, presents even to-day no insoluble problems, the question being only one of time and money. 'Interplanetary communication', he adds, 'is another matter. We must have intermediate landing places and re-fuelling stations for the machines *en route*. Fantastic and visionary as it may sound now—though I don't see why anything should be "visionary" in this scientific age—we are planning to establish "Meteor Islands" in the Stratosphere, equipped with electric power, radio broadcasters, and huge tanks containing fuel and provisions. When the first rocket leaves the earth, it can without difficulty find the "Meteor Island" whose movement will be absolutely constant and therefore can be calculated. Also the radio signals will guide us. An object hurled into the Stratosphere at a speed of 5 miles a second will, after reaching an altitude of 60 miles or more, stay there and never come back. Its speed remains constant, and as far as gravity is concerned, the law of Kepler has already established that owing to the curved surface of the earth and its rotation, such an object cannot come down. Scientists call them "Meteor Islands".

These 'islands' will correspond to what are ports of call and transhipment stations for steamers and railways on the earth. Nebel's plans include the establishment of a number of such 'stations' in space which will be the termini of the Earth Rockets, and here the rocket passengers will 'change cars' for celestial destinations! The Earth Rocket on re-fuelling will return to its terrestrial aerodrome. The power that propels the Planetary Rocket upward will act as a brake to check the speed of the Earth Rocket when it comes down within the radius of gravity. In this connection a writer in another journal points out that, if a craft which has left the earth's atmosphere comes down after 12 hours, it will probably land on the side of the earth opposite to that from which it rose. The Earth Rocket will probably therefore have to so time its return journey that it can be back at its Drome, punctual to the split second, at the end of 23 hrs. 56 m. 4·091 secs., the period of a sidereal day, that is, the time which the earth takes to make one complete rotation on its axis! In anticipation of the practicability of the 'Stratosphere Rocket', air-proof suits equipped with oxygen suppliers for the rocket passengers have already been designed.

These 'Meteor Islands', proceeds Nebel, can be used for a variety of purposes. They can be fitted with astronomical instruments. Huge natrium (sodium) mirrors, fixed at particular angles, can reflect the sun's rays and illuminate the night hemisphere of the earth! The whole earth can thus be provided with perpetual sunshine with a series of these mirrors.

By far the greatest rocket expert of the day is probably Oberth. He is a mathematician-physicist-astronomer of a high order. He has worked out a scheme for a 'Solar Space-Mirror' down to the last detail. As soon as rocket flight to a few hundred miles up becomes a reality, he hopes his space mirror will begin to take shape. Conceive an enormous mirror, 60 to 120 miles across, in operation, floating in space by itself 400 to 700 miles up and revolving round the earth by its own momentum and under the in-

fluence of the earth's attraction! The Oberth Mirror, which will thus be a new satellite of our globe, will complete one revolution round it in about 2 hrs. 45 m. at the height indicated, writes Mr. Hugo Gernsback in *Everyday Science & Mechanics* of December 1931. This mirror by reflecting sunlight on the earth can concentrate a vast amount of radiant energy—heat and light—upon any selected area on the earth's surface. It can be used to melt the polar ice. Extensive areas buried under glaciers in Greenland can be reclaimed and turned into fertile land. Harbours in the Frigid Zone can be kept free of ice all the year round. For war purposes, if utter annihilation be the aim, the mirror could burn the largest of cities to cinders. But if defeat without destruction is sought to be inflicted on the enemy, it could hurl a gigantic moving wall of fire on land, on sea or in the sky, across the paths of armies, naval squadrons and aircraft and force them all back and back! It can make short work too, if it wants, of the world's munition works and depôts. We can easily see that if war should break out in that hazy future between the country owning these mirrors and Italy or India, that country need only direct its terrible weapons against the Alps or the Himalayas and melt their snows and ice!

It is neither possible, necessary nor desirable to build on earth a mirror of this colossal size. The space rocket laden with materials will first be shot out into the Outer Atmosphere or beyond, where it will at once become a satellite of the earth like the moon! Workmen in 'space suits' and supplied with oxygen will start the construction of the mirror after arrival in free space. The mirror will consist of movable facets, for otherwise it would be only a flat or plane mirror. If made up of movable facets, it can be used both as a plane mirror to reflect sunlight over extensive areas of the earth at night, and as a curved mirror by the facets being adjusted along the lines of a parabola to form a parabolic reflector which, at will, can concentrate the sunlight on glaciers and marine ice formations or be used for war purposes.

The material to be used for the mirror will be sodium as in the Nebel Mirror, for this metal besides being not very expensive possesses high lustre and is a perfect reflector of light. On the earth it has to be kept under oil or petroleum as in the case of potassium, since it easily oxidizes when exposed to the air. In free space where air is virtually non-existent no such chemical change is possible. The sodium facets will be made in space by means of a small rolling mill attached to the outside of the space rocket. On the completion of the facets, which will be thin sheets no thinner than paper, they will be taken by the workers to the frame of the mirror. One man can carry thousands of them at a time, for objects have no weight there! By means of a 'rocket pistol' he catapults himself into the desired position and sets the sheets in their individual wire frames attached to the main net of the mirror. Millions of facets will be required for a mirror of this titanic size, and its construction will consequently take a number of years, 10 to 15 in Oberth's estimate. The whole cost is expected to amount to something like three-quarters of a billion dollars!

The question whether the sun's burning heat would melt the mirror, especially as the facets are very thin, would not arise. Most of the radiant heat would be reflected from the surfaces of these facets as the backs are coloured pitch-black, and as they are constantly exposed to the cold of space, any heat received by them would be radiated away as rapidly as it is absorbed, so that the mirror would remain unharmed.

When the mirror is completed, the crew operating it can be housed in a rocket ship hangared at the centre of the mirror at a place kept free for the purpose. Fresh crew from the earth would every week or two relieve the space crew. There will be regular communication with the earth, it is stated, by short-wave telephone*, as exceedingly

* But the possibility of such communication if the mirror is at a height of anything like 400 miles above the earth has yet to be proved. See Chapter IX, Item 4.

short waves are able to pierce the 'Radio Roof,' the top boundary of the Heaviside Layer. Telescopes will be used for observation, and by means of the short-wave telephone timely warning of icebergs ahead can be issued to approaching steamers. The plight of aviators and polar expeditions in distress can be detected and reported to the nearest ground authorities and help secured in time.

The piloting crew of the mirror could change its orbit at will by using rocket-propulsion. While racing over the northern hemisphere, if it is at any time required over the southern hemisphere, the mirror can be propelled towards that part of the earth and reach its destination in a short time probably counted only in minutes.

As the mirror keeps moving at an immense speed, it cannot concentrate its light or heat on any particular area for more than a few minutes at a time. But with a series of mirrors it would be possible to illuminate vast areas at night when desired or to provide sufficient heat in the polar regions to keep selected areas free of ice.

To revert to Nebel's 'Meteor Islands'. For voyages to the different worlds there will be different transhipment stations in space. These stations will no doubt display in prominent places huge boards reading *Change here for the Moon, Change here for Venus* and so on. A tourist bound for the farthest world in the solar system will thus find a board *Change here for Pluto*—we mean, of course, neither the lord of the nether regions nor his dreaded empire, but the trans-Neptunian planet! Should the fondest dreams of the rocket scientist be fulfilled in course of time, 'astronautics' will have been established by then as an applied science, but even then it is highly doubtful whether the traveller to Venus or to that other remote world will find at the aerodrome there any indicators *Change here for the Sun* or *Change here for the Pole Star*, though solar and stellar navigation should logically be the next stage in the rocket scientist's programme, once the moon and the planets are conquered.

Dr. Johannes Winkler, another German expert, recently constructed a rocket 6 feet high and 18 inches in diameter, which he hoped would be a forerunner to developments enabling man to reach the Moon in three or four days. Unfortunately its first test, carried out early in October 1932, proved a failure. Winkler had expected it to attain a height of 86 miles in 100 seconds, but it exploded with a deafening noise after reaching only 50 feet, when fired off from the sand-dunes near Pillau in East Prussia. The lower part of the rocket containing the combustion chamber burst into splinters. No one was hurt, but the surrounding country was enveloped in a dense cloud of smoke. The rocket carried a parachute device designed to open at its highest point of reach in the Outer Atmosphere and bring it back safely to the earth, along with the automatic instruments sent in it. It was propelled by a mixture of methyl and liquid oxygen and cost about £ 750 to build.

One of the greatest problems to be solved in the construction of the space rocket is, as has been seen, that relating to initial velocity, for the craft has to overcome the resistance of the earth's atmosphere and break away from gravity. This velocity has to be immensely higher than that of a rifle bullet or that ever attained by a cannon shell. The highest initial velocity attained by a cannon shell is 4,593 ft. a second (*vide* Chapter VIII, Item 6), which is a little over four times the speed of sound in air at ordinary temperatures. But the highest muzzle velocity of cannon shell to-day is of the order of only 2,000 ft. a second, while the initial velocity of a small bore military rifle bullet is 2,250 to 2,700 ft. and of a sporting rifle bullet 2,300 to 3,500 ft. a second. Lyon remarks that the most favourable combination of oxygen and hydrogen is unable to give a velocity of more than 3 miles a second, while according to the calculations of Winkler, the minimum speed needed to overcome the earth's gravitation as a prelude to space flight is 11,750 metres (nearly 7·35 miles) a second, *i.e.*, 26,437 miles an hour! This is a velocity which, it may be ointed out, is very nearly 12 times the

average speed of the moon in its revolution round the earth, or 1·3 times that of Saturn in its revolution round the sun! In other words, the space rocket should command a planetary velocity. Next comes the problem of catapulting the 'Meteor Island' into free space. This object will be a colossal affair, for it has hold a Rocket Drome, re-fuelling and broadcasting stations, waiting rooms and restaurants for the lunar and planetary passengers, and cabins for a staff of scientists and for the crew. What force or power could be requisitioned to shoot such a leviathan out into space scores of miles above the earth?

Some physicists say that the atomic energy locked up in one spoonful of water is powerful enough to drive a liner across the ocean and that, if they can harness this energy, all existing methods of driving machinery will go by the board and an industrial millennium be brought about. A few words may be said here with regard to the use of the term *electrical energy* as applied to atomic phenomena. That exceedingly vast forces reside in the interior of an atom has been demonstrated by various experiments, for instance, the scattering of Alpha rays, excitation of X-rays and emission of fast-moving particles. It has therefore been found necessary to express these powerful forces in suitable values, and the only appropriate values to express them in could be those used in connection with electrical energy as we ordinarily know it. The term *volt* as applied to intra-atomic energy must therefore be understood in a special manner, the correct term employed being *electron-volt*. When a statement is made that a particle of so many million volts has been ejected from an atom, it really means that a difference of potential of so many volts is required to give that particle its observed velocity. In the experiments carried out recently by Dr. J. D. Cockroft and Dr. E. T. S. Walton at the Cavendish Laboratory at Cambridge, particles were ejected with energies corresponding to 8 million electron-volts, but it does not follow that at the present stage of the world's knowledge this high electron-voltage can be converted into or employed to

obtain current of similar ordinary voltage. Besides, the experiments on splitting the atom, so far carried out in England, Germany and elsewhere, show, in the words of Lord Rutherford, the famous Director of the Cavendish Laboratory and one of the world's greatest authorities on the subject, that a disintegrating atom may often prove a sink rather than a source of energy. For, whether the internal energy of the atom is released or external energy absorbed during the process of disintegration depends very largely upon the conditions under which the experiments are carried out as well as upon the manner in which the collision resulting in disintegration takes place. It has been found, by using electric current of 600,000 volts, that on the average only one out of a hundred million particles was split by the bombardment to which they were subjected. The general opinion, therefore, among physicists who are occupied with atom-splitting experiments to-day is that physics is still a long way off being able to harness the energy released by the process of atomic disintegration to such an extent as to talk of bringing about an industrial millennium with its help. The statement of some writers that physics dreams of harnessing the internal energy of the atom for industrial purposes in the near future must, under these circumstances, be regarded as unduly optimistic.

In the article in the *Illustrated Weekly of India* referred to previously, the writer suggests free atomic energy as one of the possible forces which may be employed to hurl the 'Meteor Island' out into space. If rocket science is relying upon this energy for the realization of one part of its dream, it has to await the time when the alleged dream of physics itself is fulfilled! Many of the other problems to be solved are self-evident. Meanwhile one can well imagine the super-enthusiast among rocket experts, faced with the no less formidable problem of finding the money for his costly experimental work, sighing:— 'O for evidence that there is plenty of oil lying untapped in those distant worlds!'

Assuming that all these problems are solved in the fulness of time and the space rocket becomes an accomplished fact, let us see what sort of hospitality Dame Nature may have in store for the earthly pilgrim to her celestial dominions.

CHAPTER XIV

Physical Conditions in other Worlds

Supposing, as we have said in the last chapter, that a man-carrying rocket 'space ship' has been built which commands an initial velocity high enough to carry it to any of the other planets or to the moon, and granting that it will, in the course of its voyage, escape disaster through collision with meteors that daily hurtle across space in millions, the question still arises whether the fundamentally essential conditions of life as we know them are present in any of these worlds.

Let us first take Mercury. It was announced by the famous Italian astronomer, Schiaparelli, in 1889 that this planet rotates on its axis in the same period as it takes to complete one revolution round the sun, *i.e.*, 88 days, the value of the Mercurial year. This rotation-period was confirmed seven years later by Lowell. Baker states that its period of rotation is still uncertain. If Schiaparelli is correct, the planet would always turn the same face to the sun, so that perpetual day would reign on the illuminated hemisphere and eternal night on the unlit side. Being of all planets nearest to the sun, Mercury receives the greatest amount of heat and light. Its mean distance from the sun is 36 million miles, while that of the earth is 93 million, so that Mercury is 2·6 times nearer. As the intensity of radiant energy varies as the square of the distance from the source, Mercury should be receiving 6¾ times the solar heat received by our own planet. It is not to be wondered at, therefore, that radiometric observations show the temperature of the sunlit side of Mercury to be 340° C. (644° F.), a temperature higher than the melting points of tin and lead. The temperature will of course vary with the distance of the planet from the sun in the course of its revolu-

tion. But all the same, if human beings could migrate there, the planet's orbital motion from aphelial to perihelial position and *vice versa* would mean to them a jump 'out of the frying-pan into the fire' and back again out of the fire into the frying-pan ! Owing to the low light-reflecting power of the planet, the view is generally accepted that Mercury has little or no atmosphere, and consequently neither water nor life, so that it must be an arid and barren rock. It is fittingly described by Lowell as 'the bleached bones of a world'! As no radiation from the bright side of the planet has been detected in its other hemisphere, this side of it must be intensely cold.

In an article in *Everyday Science & Mechanics* of March 1932, Dr. Donald H. Menzel of Lick Observatory, Mt. Hamilton, California, says about this planet :—

'Science is able to reconstruct, at least in part, conditions existing upon the planet. Its surface is composed largely of solid rock. Under the merciless glare of the sun, whose brilliance is tempered by neither clouds nor oceans, the surface gets about as hot as the top of a kitchen stove under the action of a roaring fire. Water in the liquid state could not exist; if an ocean could suddenly be transported there, it would boil away with almost explosive violence. Ice would be as much a curiosity on Mercury as liquid air is to us. The depressions upon the planet would probably contain, instead of water, droplets of melted sulphur, bismuth or lead. These conclusions refer, of course, to the sunlit side of Mercury. As to conditions upon the other half, we can only venture a guess. Conduction of heat through the rocks would be negligible, and we may reasonably expect that the dark hemisphere of Mercury, perpetually exposed to the cold of outer space, would be extremely frigid. There is some possibility that both the water and air, instead of having escaped into space, may have been boiled away from the hot hemisphere and condensed upon the cold face of the planet.

'Mercury is thus a world of extremes, ranging from a temperature little short of red-hot, to a temperature not far above

absolute zero, where the ordinary gases of the atmosphere would be liquid, or perhaps even solid.'

In respect of density, mass and size, Venus is more nearly like the earth than any other planet, but its rotation-period still remains to be definitely ascertained. As twilight phenomena have been discovered on it, it follows that Venus has an atmosphere. From the high albedo or light-reflecting power of the surface of this planet, it is inferred that clouds are present in its atmosphere. Radiometric measurements reveal a uniform temperature of $-23°$ C. ($-9{\cdot}4°$ F.) at the levels of observation, *i. e.*, the surface of an upper layer of cloud, on both the day and night hemispheres. Its approximation to our globe in size and mass, combined with the presence of an atmosphere on it, suggests the likelihood of some form of life existing on the planet. Such a possibility has been opened up further by the discovery made by two astronomers of the Carnegie Institution at Mt. Wilson Observatory, California, Dr. W. S. Adams and Dr. T. Dunham, that carbonic acid gas, one of the essentials of vegetable life and therefore of animal life on the earth, is present in the atmosphere of Venus. Sunlight reflected from the planet was focussed through the giant 100-inch telescope of the observatory on to a slit in the spectroscope. The light, as it passed through the planet's atmosphere, was partly absorbed, as was shown by a dark band in the spectrum. The position of the band indicated that the gas which absorbed the light was carbon dioxide.

Mars, too, possesses an atmosphere, but in a rarefied state. Baker says that spectroscopic analysis shows its percentage of oxygen content to be less than that at the level of Mt. Everest. The discovery that for equal areas the Martian atmosphere contains not more than 5 per cent of the water-vapour present in the earth's atmosphere, shows that water may exist on the planet only in infinitesimal quantities. Seasonal changes occur on Mars as on the earth, but each season there is twice as long as ours. The

average temperature at noon in the tropical regions of the planet ranges between 7° C. and 18° C. (45° F. and 65° F.), that is, not much lower than that on our globe. But in spite of the existence of oxygen and water-vapour, though in small quantities, in the planet's atmosphere, and of cool weather in the tropics, the more eminent astronomers say that there is no conclusive evidence that animal life is present on its surface.

Jupiter also has an atmosphere, and clouds have been detected in it, but according to Jeans, no rain or water-vapour can be present in the atmospheres of the major planets. Owing to its low density and great mass, Jupiter was formerly considered to be gaseous throughout, still too hot to solidify, and hot by itself in view of its great distance from the sun. But radiometric observations give no indication of internal heat. Investigations by the astronomer Coblentz extending over ten years have shown that the temperature of the radiating layer in the Jovian atmosphere is –140° C. (–220° F.) and that this temperature is wholly due to sunshine. 'It has been suggested', says Jeans, 'that the clouds which obscure our view of Jupiter's surface may be condensed particles of carbon dioxide or some other gas which boils at a temperature far below freezing-point.'

The materials of Saturn are the least dense among all the planets. Its specific gravity is so low that it would float on water, bobbing up and down like a tennis-ball, if it fell into an ocean large enough to hold it! It resembles Jupiter in many respects in its physical constitution, and is similarly surrounded by a cloudy atmosphere. Saturn was long considered to be, like Jupiter, very hot, but radiometric measurements made by Coblentz show a temperature of –150° C. (–238° F.) on the visible levels. There is some difference of opinion as to whether this temperature is entirely the effect of sunshine or in some part due to internal heat. The general view about the observed surface of the planet is that it is gaseous.

Owing to their great distances Uranus receives only about 1/400th, and Neptune 1/900th of the heat and light which the earth receives from the sun. Menzel calculates a surface temperature for Uranus lower than –170° C. (–274°F.). In view of their low densities, both the planets must be largely gaseous like Jupiter and Saturn. The physical conditions must also be more or less similar.

The diameter of Pluto is not yet definitely known. Preliminary computations made by the Lowell Observatory indicate the Plutonic year to be probably about 260 earth-years. From later observations it is considered probable that the planet is more solid than gaseous or liquid. The sun is at so great a distance that its light must take 4 hours to reach the planet at perihelion and 7 hours at aphelion. When nearest to the sun, it would receive 1/900th, and when farthest from it, only 1/2500th of the heat and light which we on earth receive from the sun. The sun's disc would be hardly more than a pin-point of light there, yet the sunlight to an observer on the planet at aphelion would be a little over 200 times brighter than full moonlight on the earth. The Plutonic day would be 'a sort of pearly dusk, midway between day and night.'

Life as known on the earth would be totally out of the question on this frigid planet so far removed from solar warmth. Its surface temperature, says Jeans, would probably be in the neighbourhood of –230° C. (–382° F.). If the earth were transported there, not only would all its oceans, lakes and rivers freeze, but its air also would immediately solidify* and fall to the ground! Only hydrogen, neon

*** Points of Liquefaction and Solidification of Air Gases:**

	Liquefies at	*Solidifies at*
Carbon dioxide	– 78·5° C. (– 109·3° F.)	– 102° C. (– 151·6° F.)
Xenon	– 109° C. (– 164·2° F.)	– 140° C. (– 220° F.)
Krypton	– 146° C. (– 230·8° F.)	– 169° C. (– 272·2° F.)
Oxygen	– 183° C. (– 297·4° F.)	– 218·4° C. (– 361·1° F.)
Argon	– 185·7° C. (– 302·26° F.)	– 189·2° C. (– 308·56° F.)
Nitrogen	– 195·8° C. (– 320·44° F.)	– 209·85° C. (– 345·73° F.)
Neon	– 245·9° C. (– 410·62° F.)	– 248·7° C. (– 415·66° F.)
Hydrogen	– 252·7° C. (– 422·86° F.)	– 259·1° C. (– 434·38° F.)
Helium	– 268·9° C. (– 452·02° F.)	*Vide Chapter XIX.*

and helium would remain in their natural gaseous state and furnish, perhaps along with condensed ozone*, an apology for an atmosphere! It is hardly necessary to ask how man would fare in such surroundings. We know that liquid air is so cold that, if the finger touches it, the liquid at once sucks the heat out of it and the skin is badly burned. It is like touching a red-hot poker, with this difference that the rush of heat there is the other way. Liquid air boils when dropped on a cake of ice. A temperature which could solidify air would naturally be still lower than that of liquid air.

Lastly, we come to our long-neglected neighbour, the Moon. It is a cold, desolate globe of rock, waterless and barren, with no clouds, seas, rivers, lakes or vegetation. According to the Table of Densities in various parts of the Universe prepared by the Research Laboratory of the Eastman Kodak Company, the lunar 'atmosphere' is so rarefied that it contains less gas than the most perfect vacuum obtainable in a laboratory. If water at all exists on the moon, it will be in the form of snow or ice sunk very far down in the depths of its craters. If there are any inhabitants on the moon, they will find that no dust rises there, no odours are perceived and almost everywhere reigns a sepulchral silence. For all these reasons the moon is aptly described as a 'Land of Death'.

A day on the moon is as long as 354⅓ hours, *i.e.*, about 14¾ terrestrial days, and its night is of equal length. Owing to the absence of a gaseous envelope in the shape of an atmosphere, there is no twilight there as there is on earth, where this phenomenon is produced by the dispersion of sunlight by the gas molecules of the atmosphere. On the

* In the case of ozone, the boiling-point or point of liquefaction is given as −112·3° C. (−170° F.) in the *Chemical Encyclopaedia* by C. T. Kingzett, 4th edition. Liquid ozone is highly unsafe to handle owing to its liability to spontaneous explosion. We have nowhere come across any report of ozone having been frozen. The instability and dangerous properties it acquires when liquefied probably render its solidification difficult, but the *Chemical Encyclopaedia* gives its melting point or point of solidification as −251·4° C. (−420·5° F.).

moon therefore night follows day, and day follows night as suddenly as an electric light is extinguished or put on by the pressing of a switch-button! Similarly, the heat of day is rapidly followed by the cold of night, and *vice versa.*

On the earth the sun's light is scattered in all directions by the gas molecules of the air, so that places not directly reached by the sunbeams are partially lit by the diffused light. But it is not so on the moon. There being no scattering of sunlight, the shadows there are sharp and intensely black, and the most profound darkness prevails where the sun's rays do not penetrate.

Another result of the absence of an atmosphere on the moon is that its surface is ceaselessly bombarded by meteors. They rain down upon it at the estimated average rate of over a million a day and at speeds 50 to 100 times faster than a rifle bullet. The earth is free from such a fusillade, for the vast majority of these deadly missiles are burnt up or reduced to impalpable powder in the upper air owing to friction with it in the course of their fall, long before they can reach the earth.

According to the astronomers Pettit and Nicholson, the temperature of the lunar surface, that is, of the rocks on it, varies from 77° C. (171° F.) at noon to -163° C. (-261° F.) on the unlit side. The earth has a warm blanket over it in the shape of an atmosphere, which retains and accumulates the heat received during the day, and so does not part with this heat quickly with nightfall. The conditions on the moon being totally different, it begins to give up its accumulated heat rapidly with sunset. The lowest temperature occurs when the surface has cooled off during the long night on the moon. With the *burst* of day, the temperature rises quickly again.

Dr. Baker gives a vivid picture of a part of the lunar landscape :—

'The totally dissimilar landscape on the moon would impress the visitor from the earth. Absence of air and the smaller value

of gravity would produce many unfamiliar effects. A black sky instead of a blue one would be filled with stars day and night alike. The absence of any sound would be noted, except sound transmitted by the rocks. . . . . The moon is the perfect desert; for steadiness, clearness and continuity of the view of the celestial bodies, it is the perfect site for an observatory.'

The corona of the sun, its crown of glory, can be observed from the earth only at a solar total eclipse. At other times it cannot be seen owing to the scattering of sunlight by the gas molecules of the air. This scattering of sunlight makes the sky just beyond the limb of the sun thousands of times brighter than the corona. But from the moon the corona will be visible throughout the day. It forms a most sublime spectacle at sunrise in that world.

The earthly explorer of the moon will thus find a superb 'skyscape' as its one great redeeming feature, a most pleasant contrast to its forbidding physical features, for the lunar surface will be, as Professor John Q. Stewart of Princeton University describes it, 'a mineral jungle—steep spines of bright rock, level expanses of darker slag, tumbled masses of ore, ashes from ancient volcanoes and wrecks of meteorites.' Clad in the rocket scientist's space suit, breathing oxygen all the time, he could climb with ease to the crest of the highest lunar peak, for he would have to put forth only one-sixth of the exertion required for a similar ascent on the earth. As a protection from the incessant fusillade of meteors, he would probably also be wearing a massive steel helmet, since he would not mind sustaining a weight which is similarly reduced to one-sixth! Let us imagine him arriving at the mountain top at sunrise. As he scans from there the vast black firmament spangled with stars shining with extraordinary brilliancy, with the sun's resplendent disc peeping from above the horizon, with the mellower pearly streamers of its corona flung far out into space, no wonder if his feeling be a thousandfold deeper than that of the

poet as he surveyed the heavens at night from the Alpine heights of Chamonix :—

> ' While on this lofty mountain,
>   We seem to Heaven so near,
> We seem to hear the chorus
>   Of every rolling sphere.'

CHAPTER XV

Asteroids and Comets

Asteroids, otherwise called Planetoids, are minor planets revolving in close orbits round the sun between the paths of Mars and Jupiter. Their total number has been estimated at over 100,000. The largest, Ceres, is 480 miles and the smallest less than 5 miles in diameter. The brightest is Vesta, the only asteroid that can be seen with the naked eye under favourable conditions. It is 243 miles across. For a long time it was believed that the body which comes nearest to us among all the members of the planetary system is the asteroid Eros. But very recent observations show that this unique position belongs to another planetoid which has been provisionally named *1932 HA* or *Reinmuth Planet*. It approached the earth on 16th May 1932 to a distance of a little more than 6 million miles. It is described as a very small body, 2 to 3 miles across, which requires even when nearest a fairly powerful telescope to detect. Its path lies partly within that of the earth and for a short distance inside that of Venus, and as this orbit is tilted with respect to that of our planet, a collision with the earth is outside the bounds of possibility. An article in *Popular Science Monthly* of August 1932 gives some particulars regarding this new body supplied by Dr. F. L. Whipple of the Harvard Observatory, Cambridge, Massachusetts, who was the first astronomer to observe it in America. It is a jagged mass of rock, more likely to be irregular than spherical, and in view of its low light-reflecting power, its surface must be rough and covered with great masses of crags. A human visitor would find it airless and would be exposed to violent extremes of temperature which would alternately scorch and freeze him. At its closest approach to us when it is less than 2½ million miles away, an observer stationed upon it could obtain, with a pair of field-glasses, a good view

of the earth and clearly see its continents. Whipple sounds another note of warning to the imaginary visitor. Even if the other difficulties present on the planetoid could be overcome, he should move with the utmost caution, for its force of gravity is so feeble that, were he to take a strong leap, he would 'bound clear off the planetoid, never to return!' And with what further result? He would revolve round the sun like the asteroids and planets in an elliptical orbit of his own as one more member of the Solar System! In other words, to us on the earth he would become a permanent heavenly body!

The orbits of most asteroids are highly eccentric. Asteroid *T G*, discovered in 1906, has its orbit so eccentric that it sometimes goes far beyond the path of Jupiter. For a similar reason, Eros at perihelion comes within the orbit of Mars, while at aphelion it travels far beyond. The revolution-periods of these bodies range from less than two years to nearly nine.

Comets are strange heavenly bodies, which vary in appearance, size and brilliancy. Their total number in the Solar System has been estimated at 120,000. The vast bulk of them are invisible to the naked eye, but some are so big and bright that they can be seen in broad daylight though they may be in the close vicinity of the sun.

Comets usually consist of two parts, the *coma* and the *nucleus*. The coma is a small rounded cloud of luminous fog, with an average diameter of 80,000 miles, but in the great comet of 1811 it attained a record diameter of a million miles. In the centre of the coma is a bright point of light, the nucleus, and together they form the 'head' of the comet. A large comet has, besides, a luminous tail, sometimes more than one, and the tail is occasionally so long that it stretches across the heavens from the sun to the earth or rather from the zenith to the horizon. The great comet of 1882, which was visible for over a week, had a tail upwards of 100 million miles long.

One of the pious prayers among the Christian people in mediaeval times was:—'Lord, deliver us from the Devil,

the Turk and Comet!' Comets were therefore closely watched by the ancients, with the result that they kept careful records of their observed returns. The astronomers Cowell and Crommelin at Greenwich were able to trace from these records 28 returns of Halley's Comet observed since as far back as 240 B. C. Aristotle however mentions the appearance of a comet still further back, *viz.*, in the year 372 B. C.

An interesting article under the caption 'Exit the Earth!' contributed by Sir Richard Gregory to *The Sunday Despatch* was reproduced in the *Evening News of India* of 1st August 1929. A few extracts from it may be quoted as bearing on the subject of the present chapter:—

'From time to time the sun pulls into our system solid masses of matter, some of which might eventually cross the earth's track at the same time as the earth. Most of the large comets which have appeared have been captured in this way by the attraction of the sun and the planet Jupiter. Exactly what the nucleus of the head of a comet is cannot definitely be said, but in all probability it consists of a collection of solid particles which may be the size of small marbles or of footballs, or even larger.

'The total mass of a comet can be anything from 1/100000th to 1/10000th the mass of the earth.

'Nearly all of a comet's substance is concentrated in the nucleus, and this may have a diameter of about a couple of thousand miles—say a quarter the diameter of the earth—or as in Halley's periodic comet, which was visible in 1910, of about 500 miles.

'An encounter of the earth with the nucleus of a comet would mean the end of the world. Such a collision is not probable, but it is not impossible. We passed through the tail of Halley's Comet in 1910, and also through the tail of another comet in 1861, but that is a very different thing from passing through the head.

'The tail of a large comet, though it looks very alarming, really consists of extremely attenuated gas, and no effect whatever is noticed when it envelops the earth.

'If, however, we hit the nucleus of a comet, the friction and collision with the solid material in it would probably produce so much heat that all forms of life would be destroyed, and our world would be transformed into a barren rock.

'By the laws of probability or chance, the earth must have had collision with comets in the course of its history, and others will occur in the future.'

In one of his lectures Jeans makes a humorous remark on the comet and its erratic ways:—

'Comets are the crazy lunatics of space. They dash about in orbits it is very difficult to predict. They may not come back, because they have met with an accident on the way. The comet ...ke the man who runs amok so as to get his name in the ...dlines of the newspapers. They have a brief and glorious ...e through behaving indiscreetly.'

A comet's tail consists of materials of high tenuity and is so transparent that it is possible to see most stars through it undimmed in their luminosity.

Comets shine partly by their own light and partly by the reflected light of the sun. The spectroscope shows that most of their envelopes are composed of the gases cyanogen, carbon monoxide and hydrocarbons and the vapours of sodium, iron and other metals. It is not to be assumed from this that comets are simply masses of gas moving across space. Though the quantity of matter in a comet may be extremely small, it is likely that its nucleus contains a swarm of small solid particles, each being surrounded by gas. In the great comet of 1882 observed by Copeland and Lohse, the spectrum revealed the presence of sodium and manganese in its interior.

The orbits of comets are eccentric, to such an extent in the case of some that their perihelial points actually lie within the corona of the sun. The orbits vary in their form. The paths of some of the comets are represented by a more or less elongated ellipse, the curve being thus a closed one. These regularly revolve round the sun. The orbits of the remaining comets are open curves, those of

the majority being parabolic and of a few only hyperbolic. It may be explained that, in a parabola, the arms of the figure become nearly parallel to each other as they extend farther out, while in a hyperbola they go on diverging from each other.

More than 100 comets are known to have distinctly elliptical orbits. 40 per cent of them have been found to have revolution-periods of between 5 and 9 years, while the periods of the rest range up to 10,000 years. Halley's Comet takes about a human lifetime to complete its circuit round the sun. Comets moving in unclosed orbits approach the sun from remote distances far beyond the Solar System, but after sweeping round the sun, retreat into the depths of space, perhaps never to return.

The name 'comet' is derived from the Greek *kometes*, a term which means 'long-haired' and applies to the appearance of the tail. The ancients, practically the world over, held this body in superstitious dread. Comets were looked upon as the harbingers of nation-wide calamity and disaster.

In the light of the above quotations from two great scientists, it is no wonder if the ancients entertained a holy horror for comets, and looked upon them as Jeans does, as road-hogs of the universe!

Both Jeans and Gregory have some remarks to make, nearly as impressive, about asteroids. Says the former:—

> 'If asteroid Ceres which weighs 8,000 times less than the earth were stopped in its orbit, it would gravitate towards the sun, slowly at first and then with ever-increasing velocity. If the earth happened to be in its way, it would collide with it at the speed of a shooting star and would raise it to a white heat. Needless to say, all life would be blotted out. But the more massive of the asteroids would not be easily disturbed in their orbit.'

Gregory adds in his article :—

> 'There are other bodies in the solar system with which the earth could land an accidental but disastrous meeting.

'In 1931, for example, an asteroid called Eros—one of a group of some thousands which circulate round the sun between the planets Mars and Jupiter—will come within a distance of 16 million miles of the earth. It is only 15 miles across, and there is no need to fear that it will come into contact with the earth, but on the other hand no one can say it is impossible for this or another asteroid to strike the earth and thus bring about the actual destruction of life upon the world.

'Even if there was no end on collision, the near approach of any such object to the earth would cause tidal and other effects on the surface and in the interior which would bring disaster to most parts of the world.'

The calculation of the probable weights of Comets and the largest Asteroid is very simple. From the extracts quoted it will be seen that Asteroid Ceres weighs, according to Jeans, 8,000 times less than the Earth. Its weight would therefore be, in round figures, 824 quadrillion tons! The most liberal estimate assigns a total mass of 1/500th of that of the earth to the whole family of Asteroids, so that their combined weight should not exceed 13 quintillion tons or one-sixth of the weight of the Moon. Gregory estimates, as has been noticed, the total mass of a Comet at from 1/100000th to 1/10000th of that of the Earth. This means that the weights of Comets vary between 66 and 660 quadrillion tons.

CHAPTER XVI

The Lower Stellar Region

Ye multiplying masses of increased
And still increasing light: what are ye? What
In this blue wilderness of interminable
Air where ye roll along, as I have seen
The leaves along the limpid stream of Eden?
Is your course measured for ye? Or do ye
Sweep on in your unbounded revelry
Through an aerial universe of endless
Expansion, at which my soul aches to think,
Intoxicated with eternity?

—*Byron*

Stars are hot, self-luminous bodies, composed of glowing vapours like the sun. Stars become exceedingly dense towards the centre, and the central temperatures of those stars whose distribution of mass is stable are of colossal values and in the denser stars may amount to scores of million degrees C.

Such a phenomenal heat would be enough to split all the atoms inside the stars, but according to Millikan, whilst these atoms are committing suicide in pairs, each negative electron taking a positive mate with it into annihilation, there is indication that new atoms are being formed millions of miles away from the stars. While matter is thus destroyed in the interior of a star and turned into radiation, remarks Professor Milne of Oxford in this connection, this conversion of matter into energy supplies it with the enormous energy needed to keep it shining through the ages.

But the theory that fresh atoms are being built up in the universe to replace those broken up is vehemently contested by Sir James Jeans and also by Sir Arthur

Eddington, the distinguished Plumian Professor of Astronomy at Cambridge University. The former holds that, while everywhere in the universe the higher and more complex forms of matter are slowly disintegrating, no instance of the contrary process of building up matter is known, so that the universe is like a clock which is running down. Eddington points out that cosmic rays are evidence against Millikan's conclusion. He contends that these rays are the 'souls' of disintegrating atoms and that in course of time the last erg of atomic energy will be gone. Unless we can turn time backward, he adds, the planets and the stars will gradually die down into cosmic dust.

The pressure at the sun's centre, as has been already mentioned, is 36 billion atmospheres, while at the centre of a star whose mass is one and a half times the sun's, the pressure is estimated at only 21 million atmospheres. Still it means more than 137,800 tons to the square inch or 6 times the pressure at the centre of the earth!

The composition of stellar atmospheres has been ascertained by means of the spectroscope. The elements most abundant in them are hydrogen, helium, oxygen, carbon, silicon, iron, calcium, sodium, aluminium, zinc, magnesium and manganese.

The largest telescope in existence—the 100-inch instrument at Mount Wilson in California—shows about a billion and a half stars. The 'super-giant' 200-inch telescope now under construction in America will show many more, but even then we are told we shall be able to see a small fraction of the total number of stars in the universe. Their total number is estimated by Jeans at over 100 billion, of which persons with the keenest sight can see with the naked eye only about 3,000. But even this estimate of 100 billion is, of course, more or less a speculation, and the total number of stars in the heavens may be still greater. As bearing on this point, may be quoted the following lines from the poet, Allingham :—

'But number every grain of sand,
Wherever salt wave touches land;
Number in single drops the sea;
Number the leaves on every tree,
Number earth's living creatures, all
That run, that fly, that swim, that crawl;
Of sands, drops, leaves, and lives, the count
Add up into one vast amount,
And then for every separate one
Of all those, let a flaming SUN
Whirl in the boundless skies, with each
Its massy planets, to outreach
All sight, all thought: for all we see
Encircled with infinity,
Is but an island.'

Stars are of various degrees of brightness. The term *magnitude*, as used in the following list, does not indicate size, but brightness. Thus the brightest stars are said to be of the *first magnitude*, the next in brightness of *second magnitude*, and so on. Some stars undergo a periodic change in their brightness and are consequently called *variable stars.*

According to Argelander, the number of stars of the first three magnitudes are:—

1st	magnitude—	20
2nd	„ —	65
3rd	„ —	190

The following table gives the results of the observations made in 1925 by F. H. Seares and P. J. Van Rhijn as to the approximate number of stars of lesser magnitudes:—

Magn.	No. of Stars	Magn.	No. of Stars
4th	530	12th	2,270,000
5th	1,620	13th	5,700,000
6th	4,850	14th	13,800,000
7th	14,300	15th	32,000,000
8th	41,000	16th	71,000,000
9th	117,000	17th	150,000,000
10th	324,000	18th	296,000,000
11th	870,000	19th	560,000,000

The number of stars of 20th magnitude is, according to Dr. Baker, 1 billion. It will be noticed that, as we go down from the greater to the lesser magnitudes, the number increases roughly in geometrical progression till the 15th magnitude.

Stellar distances are so vast that they are mentioned in terms of a unit called *Light Year*, a light-year being the distance travelled by light in one year. The velocity of light as determined by Michelson in 1924 at Mt. Wilson (California), is 186,285 miles a second. A light-year is therefore equal to about 5,875,000,000,000 or nearly 6 trillion miles. The distances of stars are ascertained by measuring their parallaxes by certain methods. *Parallax*, in its broad sense, is the difference in the direction of a celestial object as observed from two different points, and is measured by the angle formed by two lines drawn from the body to the two points. But usually the term is used for the angle between the two lines joining the body to the observer and the earth's centre; in other words, it is the angle subtended at the object by the earth's radius. In the case of a star, however, from which the earth would be seen as only a point, the parallax measured is the angle subtended at the star by the sun's mean distance from the earth, *i. e.*, by the radius of the earth's orbit. When the parallax has been determined, the distance is easily calculated by trigonometry.

Stellar distances, except in the case of the most important stars, principally those of the first magnitude, are a subject of continuous research. It is difficult to trace the approximate distances of stars of the 2nd and lesser magnitudes except in a few cases. In this chapter, generally the figures given by Abbot and Baker have been adopted, and in only a few instances, the distances are taken from Scientific journals. In the case of stars of other than 1st magnitude where the individual distances are not traceable, are given the average distances computed from the mean parallaxes as given by Baker. These distances, however, must be looked upon rather as conservative estimates, and

the actual average distances must be much higher, for Baker is careful to explain that the mean distance of stars of a given magnitude is considerably greater than the distance derived from the mean parallax for that magnitude.

Where available, the diameters of some of the larger stars have been given. The diameters of the exceptionally big stars have been ascertained by means of a 20-ft. interferometer, an instrument used as an attachment to the giant 100-inch reflecting telescope at the Mt. Wilson Observatory in California. A new 50-ft. interferometer has been demonstrated by Dr. F. G. Pease of this Observatory, and he has measured the diameters of a number of gigantic stars with its aid.

The heat of stars is measured by means of delicate instruments called the Radiometer and the Thermocouple.

For the most part the well-known stars are dealt with in the following list. Wherever it has been possible to trace them, are given side by side, as a matter of interest, the names of the stars and constellations as known in Hindu astronomy. The abbreviation *L. Y.* stands for *light-years.*

Some idea of the immensity of space will be gained from the fact that the nearest star is nearly 260,000 times farther away from us than the sun, or about 5,115 times farther than is the farthest of planets, Pluto, at its greatest distance from the earth. Further, if it were possible to build a man-carrying 'space ship' which could sail into the stellar region and travel with the phenomenal velocity of light, it would take the astronaut fully two months to journey from the nearest star to the next nearest; and to reach from the earth any of the faintest stars visible to the naked eye, it would take him something like 30 centuries!

		Approximate distance from the Earth
(1)	Proxima Centauri—nearest of all stars, a very faint one. Parallax 0·786"—11th magn.	4·15 L. Y. = 24 trillion miles

Note.—It belongs to the group Centaur, part of a southern Constellation, in the form of a Centaur, usually joined with the Constellation Lupus, the Wolf. The star is of a red colour. Its luminosity is only 1/10000th of the sun's. Its surface temperature is 3,000° C.—(*Jeans*).

	Approximate distance from the Earth
(2) *Alpha Centauri*—'Mitra' in Hindu Astronomy — 1st magn. as a double star	4·3 L. Y.= 25 trillion m.

Note

Alpha Centauri belongs to what is called the *binary system.* A binary star consists of two stars lying close together and revolving round each other by mutual gravitation. The brighter component of Alpha Centauri is of a yellow colour and is called Alpha Centauri *A*, and the other Alpha Centauri *B*. The diameter of *A* is about 917,960 miles, and it is thus a little larger than the sun.—(*Jeans*). The diameter of *B* is still larger, being about 1,056,520 miles. —(*Jeans*).

This 'physical couple' is said to be the third brightest star in the heavens. Its surface temperature is 6,000° C. or about the same as that of the sun, and its parallax is 0·758″.—(*Baker*).

'An observer placed on Alpha Centauri and viewing the solar system from the awful distance which intervenes, would see the earth describe a little circle about a second and a half in diameter. This is extremely small; it is about as large as a penny piece would look if placed 3 miles from the observer.'—Ball in his book, *In the High Heavens.*

N. B.—A second and a half, in the duodecimal system, equals one-eighth of an inch. Ball obviously refers here to a telescopic view.*

(3) *Sirius* or Dog Star—'Vyādha' or 'Lubdhaka' in Hindu Astronomy —in southern Constellation Canis Major or Great Dog—1st magn.	8·8 L. Y.(*Baker*) = 52 trillion m.

* Dr. Donald H. Menzel of Lick Observatory, Mt. Hamilton, California, says in *Everyday Science & Mechanics* of September 1932 that the biggest telescope in the world, if transported to the nearest star and then turned back upon the solar system, would be unable to show even the largest of our planets.

Note

Sirius also is a binary star. Sirius *A*, the main star, is of a brilliant white colour. It is the brightest star in the heavens and is hence called the 'Gem of the Sky'. It is 26·3 times as bright as the sun. Though it is over twice as distant as Proxima Centauri, we receive from it 70,000 times as much light. Its diameter is 1,558,800 miles.—(*Baker*). Sirius is thus over 7 million times as large as the earth, or nearly 6 times larger than the sun. It is therefore classed among the 'Giant Suns'. Its surface temperature is 11,200° C.—(*Baker*).

Sirius is associated by the Hindus even to this day with the heat of summer, as the star, being then directly overhead in daytime, is believed to intensify the heat poured forth by the sun. They consequently often call this star *Agninakshatra*, which means 'Fiery Star'. The Romans called the hottest days of summer *caniculares dies* (dog-days), the days of the Dog Star, for according to their theory this star, rising and setting with the sun, added to its heat during the dog-days, so that the earth received the combined heat of the two luminaries. The dog-days last 40 days, 20 before and 20 after the heliacal rising of the star, commencing on the 3rd of July and ending on the 11th of August.

Sirius *A* has a remarkable companion called Sirius *B*, whose material is so dense that it is said that a ton of it could be easily packed in a match-box! It may be added by way of comparison that the densest terrestrial substance known is the metal Osmium, which is about 22·5 times denser than water, while the average density of the material of Sirius *B* has been found to be, according to Baker, of the order of 30,000 (Dr. Smart says 50,000 and Sir James Jeans 'about 60,000') times that of water, *i.e.*, at least 1,333 times that of the densest-known substance in our globe. The diameter of the star is about 25,000 miles, so that it is about 30 times larger than the earth.

But this record in density fades into the background before that claimed by Van Maanen's Star. It is the smallest star yet discovered and may not be larger than the earth. The mean density of the substance of this curious body, says Jeans in one of his arti-

cles, is probably about 50,000 times that of the earth, *i.e.*, 276,000 times that of water or over 12,000 times that of osmium! The explanation he gives is that in this star the material is packed exceedingly closely 'by the simple expedient of breaking up the atoms and jamming the ingredients together.' Its surface temperature is 7,000° C.—(*Jeans*).

	Approximate distance from the Earth
(4) *Procyon* or Alpha Canis Minoris—'Prabhāshaka' in Hindu Astronomy — 1st magn.	10·4 L. Y. (*Baker*) = 61 trillion m.

Note.—It is a pale-yellow double star in the southern Constellation Canis Minor or Little Dog. Its diameter is 1,645,400 m. and surface temperature 6,500° C.—(*Baker*). Another Giant Sun. It is 5½ times as bright as the sun.

(5) Epsilon (Greek letter) Eridani—in Eridanus, a winding Constellation in the southern hemisphere	10·5 L. Y. = 61 trillion m.
(6) 61 Cygni—in northern Constellation Cygnus or Swan or Northern Cross and in Zodiacal Constellation Aquarius (*Kumbha* in Hindu Astronomy) — 5th magn.	10·9 L. Y. = 64 trillion m.

Note.—Its surface temperature is 3,800° C. — (*Baker*).

(7) *Altair* or Alpha Aquilae—'Shravana' (श्रवण) or 'Ashvattha' in Hindu Astronomy—in northern Constellation Aquila or Eagle — 1st magn.	16 L. Y. (*Baker*) = 94 trillion m.

Note.—A star of a faint white colour. Diameter 1,212,400 miles and surface temperature 8,600° C.—(*Baker*). Another Giant Sun. It is over 9 times brighter than the sun. *Shravana* is the 22nd lunar mansion (asterism or constellation) in Hindu Astronomy, consisting of 3 stars of 1st, 3rd and 4th magnitudes respectively.

(8) *Fomalhaut*—in southern Constellation Piscis Australis or Southern Fish — 1st magn.	24 L. Y. (*Baker*) = 141 trillion m.

Note.—It is a white star and is 13½ times as bright as the sun.

Approximate distance from the Earth

(9) *Vega* or Alpha Lyrae—'Abhijit' in Hindu Astronomy — in northern Constellation Lyra — 1st magn.
26 L. Y. (*Baker*) = 152 trillion m.

Note.—A brilliant white star 50 times brighter than the sun. Diameter 2,078,400 m. and surface temperature 11,200° C.—(*Baker*). Another Giant Sun.

(10) *Pollux* or Beta Geminorum—'Punarvasu' in Hindu Astronomy — 1st magn.
32 L. Y. (*Baker*) = 191 trillion m.

Note.—A reddish star 28 times as bright as the sun. In Hindu Astronomy the Zodiacal Constellation Gemini or Twins is known as *Mithuna*. *Punarvasu* is the 7th lunar mansion consisting of 4 stars, one of which is of 1st magn.

(11) Eta (Greek letter) Hercules — in northern Constellation Hercules
39·5 L. Y. = 232 trillion m.

(12) *Arcturus* or Alpha Bootes—'Svāti' or 'Nishtya' in Hindu Astronomy —in northern Constellation Bootes — 1st magn.
41 L. Y. (*Baker* and *Smart*) = 241 trillion m.

Note.—A red star 100 times as bright as the sun. Diameter 25,980,000 m. and surface temperature 4,100° C. —(*Baker*). Another Giant Sun.

Svāti is the 15th lunar mansion consisting of one star, which is of the 1st magn.

(13) Castor or Alpha Geminorum—a double star of 2nd magn.
43 L. Y. (*Baker*) = 253 trillion m.

(14) *Capella* — 'Brahmahridaya' in Hindu Astronomy — in northern Constellation Auriga or Charioteer—1st magn.
47 L. Y. (*Baker*) = 276 trillion m.

Note.—A star of yellowish-white colour, 185 times brighter than the sun. Diameter 10,392,000 m. and surface temperature 5,600° C.—(*Baker*). Another Giant Sun. Capella, Arcturus and Vega are three of the most brilliant stars in the northern heavens.

(15) Nearest Star or Stars in northern Constellation Ursa Major or Great Bear or Big Dipper or the Plough—Constellation *Saptarshi* in Hindu Astronomy consisting of 7 stars, of which 6 are of 2nd magn. and 1 of 5th magn.
50 L. Y. = 294 trillion m.

Note.— The above distance is taken from a chart of the astronomical or visible universe, accompanying an article by Mr. John T. Brady in *Popular Mechanics Magazine* of April 1930.

According to Hindu mythology, seven Rishis or Sages, or Saptarshis, form this constellation. They belong to the Brahmarshi or highest order. Their names, according to the Hindu epic of Mahābhārata, are Marichi, Atri, Angiras, Pulastya, Pulaha, Kritu and Vashishta.

		Approximate distance from the Earth
(16)	Polaris or Pole Star—'Nakshatra-némi,' 'Jyôtiratha' or 'Dhruva-nakshatra' in Hindu Astronomy —chief star in the northern Constellation Ursa Minor or Little Bear—a white star—2nd magn.	54·5 L. Y. = 320 trillion m.

Note.—This distance is taken from Millikan and Gale's *Practical Physics*, which mentions it in the following interesting way :—

'If an observer on the Pole Star had a telescope powerful enough to enable him to see events on the earth, he would not have seen the battle of Gettysburg (which occurred in July 1863) until January 1918.'

According to Hindu mythology, Dhruva was the son of the king Utthānapāda, who had two wives, Suruchi and Suniti, but the latter was disliked by the king. Suruchi had a son named Utthama, and Suniti another named Dhruva. One day Dhruva tried, like his elder brother, to sit in his father's lap, but was spurned by the king and his favourite wife. The poor boy went sobbing to his mother, who told him in consolatory terms that fortune and favour could only be attained by hard exertion. The youth thereupon left the paternal roof, retired to the forest and though quite a boy, performed such rigorous austerities that he was at last raised by the god Vishnu to the position of the Pole Star.

(17)	*Regulus* or Cor Leonis (Lion's Heart)—'Maghā' in Hindu Astronomy, in the Zodiacal Constellation *Simha* (Leo)—1st magn.	56 L. Y. (*Baker*) = 329 trillion m.

Note.— It is 70 times as bright as the sun. Its diameter is 4,330,000 miles. Another Giant Sun. *Magha* is the 10th lunar mansion consisting of 5 stars, of which 1 is of 1st, 1 of 2nd and 3 of 3rd magnitudes.

Approximate distance from the Earth

(18)	*Aldebaran* or Alpha Tauri or Bull's Eye—'Rohini' (रोहिणि) in Hindu Astronomy, in the Zodiacal Constellation *Vrishabha* (Taurus)—1st magn.	57 L. Y. (*Baker*) = 335 trillion m.

Note.—A red star 90 times brighter than the sun. Diameter 32,908,000 m. and surface temperature 3,300° C.—(*Baker*). Another Giant Sun.

Rôhini is the 4th lunar mansion consisting of 5 stars, of which one is of 1st magn.

(19)	*Achernar* or Alpha Eridani—in the southern hemisphere—1st magn.	66 L. Y. (*Baker*) = 388 trillion m.

Note.—A blue-white star 200 times as bright as the sun. Another Giant Sun.

According to Smart, the number of stars whose distances are between 8 and 66 *L. Y.* is 309.

Average distance from the Earth

Stars of the 2nd magnitude (except one or two mentioned later) whose individual distances are not available :—	74 L. Y. (*Baker*) = 435 trillion m.

(20) Alpha Draconis—in northern Constellation Draco or Dragon.

(21) Brightest Star in 'Ashvini', the 1st lunar mansion in Hindu Astronomy consisting of 3 stars in the Zodiacal Constellation 'Mésha' (Aries).

(22) Brighter of the 2 Stars in 'Purva Phalguni' (पूर्व फल्गुनि) or 'Arjuni', in Hindu Astronomy the 11th lunar mansion in Leo.

(23) Denebola or Beta Leonis—in Hindu Astronomy 'Utthara Phalguni', the 12th lunar mansion consisting of 2 stars in Leo, both of 2nd magn.

(24) 2 of the Stars in southern Constellation Corvus or Raven—in Hindu Astronomy 'Hastā', the 13th lunar mansion consisting of 5 stars in the Zodiacal Constellation 'Kanyā' (Virgo).

(25) Brighter of the 2 stars in *Vishakha* (विशाखा) or *Radha* (राधा), in Hindu Astronomy the 16th lunar mansion in Zodiacal Constellation 'Tulā' (Libra).

(26) Brightest Star of the four in *Anuradha* (अनुराधा), in Hindu Astronomy the 17th lunar mansion in Zodiacal Constellation *Vrischika* (Scorpio).

(27) Alphecca or Gemma in Constellation Corona Borealis or Northern Crown.

(28) Brightest Star in *Mula* (मूला), in Hindu Astronomy the 19th lunar mansion in Scorpio, consisting of 9 stars, one of which is of 2nd magn.

(29) Brightest Star in 'Uttharāshādhā', in Hindu Astronomy the 21st lunar mansion in Zodiacal Constellation *Dhanu* (Sagittarius), consisting of 3 stars.

(30) Markab or Alpha Pegasi—in Hindu Astronomy one of the 2 stars (both of 2nd magn.) in 'Purvābhādrā' or 'Purvābhādrapadā' (पूर्वाभाद्रपदा) or 'Pratishthāna' (प्रतिष्ठान), the 25th lunar mansion.

Note—Markab is a white star in the northern Constellation or 'Square' of Pegasus called the 'Flying' or 'Winged Horse.'

(31) Algenib or Gamma (Greek letter) Pegasi—'Gôpāda' in Hindu Astronomy—in the Square of Pegasus.

(32) Alpheratz—in northern Constellation Andromeda—'Uttharābhādrā' or 'Uttharābhādrapadā' in Hindu Astronomy, the 26th lunar mansion in Zodiacal Constellation *Meena* (Pisces), consisting of 2 stars both of 2nd magn., identified as Alpha and Beta Andromedae respectively.

(33) Alpha Hydrae— in Southern Constellation Hydra or Sea Serpent, known in Hindu Astronomy as 'Ashlésha' (आश्लेषा) or 'Nāganāyaka' or 'Nāga-nakshatra', the 9th lunar mansion in Zodiacal Constellation 'Karkātaka' (Cancer) consisting of 5 stars, one of which is of 2nd magn.

	Average distance from the Earth
Stars of the 3rd magn. (except one or two mentioned later) whose individual distances are not available:—	102 L.Y. (*Baker*)= 599 trillion m.

(34) Brightest Star in northern Constellation Delphinus or Dolphin — 'Shravishtā', 'Dhanishtā' or 'Vasudévatā' in Hindu Astronomy, the 23rd lunar mansion in Zodiacal Constellation Aquarius, consisting of 4 stars.

(35) Gamma Andromedae—a double star, one of 3rd magnitude of orange colour, and the other of lesser magnitude of green colour.

(36) Brightest Star or Stars in Constellation 'Shatabhīshā', in Hindu Astronomy the 24th lunar mansion in Zodiacal Constellation Aquarius, consisting of 100 stars.

(37) Brighter of the 2 Stars in 'Purvāshādhā', in Hindu Astronomy the 20th lunar mansion in Zodiacal Constellation Sagittarius.

(38) Beta Cygni — a most beautiful, coloured double star—one of 3rd magn. of a golden-yellow colour, and the other of 7th magn. of a light blue colour.

	Approximate distance from the Earth
(39) Algol or Beta Persei in northern Constellation Perseus	115 L.Y.(*Encycl. Br.1929*)= 675 trillion m.

Note.—Algol is a variable star and is hence called 'The Winking Demon Star'. It varies from 2nd to 4th magn. in about 2 days 21 hours,

and returns to its original brightness in the same interval of time. It is a brilliant star with a luminosity 140 times that of the sun. Its diameter is 2,675,000 m. (*Encycl Brit., 1929*). Another Giant Sun. It has a faint or dark companion whose diameter is, strangely enough, still larger, *viz.*, 3,062,500 m. (*Encycl. Brit., 1929*), giving us still another Giant Sun.

(40)	Hyades, a Cluster of 5 Stars in Zodiacal Constellation Taurus	130 L. Y. (*Brady*) = 764 trillion m.

Average distance from the Earth

Stars of the 4th magn., whose individual distances are not available :—	142 L. Y. (*Baker*) = 834 trillion m.

(41) Eta Cassiopeia—in northern Constellation Cassiopeia or Lady's Chair—Constellation 'Sharmishtā' in Hindu Astronomy—a coloured double star, one of 4th magn., yellow, and the other of 8th magn., purple.

(42) Brightest Star in Constellation 'Bharani' (भरणी), the 2nd lunar mansion in Hindu Astronomy, consisting of 3 stars.

(43) Delta (Greek letter) Cancri—brightest star in Constellation 'Pushyā,' the 8th lunar mansion in Hindu Astronomy, in Zodiacal Constellation Cancer, consisting of 3 stars.

(44) Iota (Greek letter) Cancri—a double star, one of 4th magn. of orange colour, and the other of 6th magn. of blue colour.

(45) Brightest Star or Stars in Constellation Piscium—Constellation 'Révati' in Hindu Astronomy, the 27th or last lunar mansion, consisting of 32 stars.

Approximate distance from the Earth

(46)	Mira or Omicron (Greek letter) Ceti, or 'The Wonderful'—a variable binary star	163 L. Y. (*Baker*) = 958 trillion m.

Note.—It is in the Cetus or Whale, a large constellation in the southern hemisphere. It is of a red colour. It varies from 6th to 9th magn. in 331

days and then returns gradually to its original brightness in the same interval of time. When brightest it is 500 times brighter than when faintest. Its diameter is 259,800,000 m.—(*Baker*). Another Giant Sun.

	Average distance from the Earth
Stars of the 5th magn. whose individual distances are not available :—	192 L. Y. (*Baker*) = 1 quadrillion & 128 trillion m.

(47) Brightest Stars in Constellation Corona Australis or Southern Crown

	Approximate distance from the Earth
(48) *Betelgeuse* or Alpha Orionis—'Ardrā' (आर्द्रा) or 'Bāhu' in Hindu Astronomy—in southern Constellation Orion or Hunter ('Mrigashirā' in Hindu Astronomy)—1st magn.	192 L. Y. (*Baker*)= 1·128 quadrillion m.

Note

Orion is the most remarkable of all Constellations. It contains 2 stars of the 1st magn. and 5 of the 2nd, and has in its vicinity a number of very brilliant stars. The splendid 1st magn. star, Sirius, sparkles like a gem in the line of belt downwards to the left, while another giant star of the 1st magn., Aldebaran, in Constellation Taurus, pours forth its lustrous glow from a point above to the right.

Betelgeuse is a red star 1,200 times as bright as the sun. It varies in its size, but its maximum diameter is 260,000,000 m.— (*Baker*). Another Giant Sun. Its surface temperature is 2,700° C.— (*Abbot*).

The ancient Hindus gave the name of *Mrigashirā* to Orion, as they saw in it a resemblance to the head of a deer pierced with a triple-jointed arrow. The Rig-védic version connecting the deer's head with the constellation is that it is the head of the demon Vritra (supposed to be the personification of darkness and drought) in the form of this animal, struck off by the storm-god Indra. In Hindu Astronomy, *Ardrā* or *Bāhu* is the 6th lunar mansion consisting of one star only, and the Constellation *Mrigashirā* forms the 5th lunar mansion consisting of 3 stars.

		Approximate distance from the Earth
(49)	Scheat or Beta Pegasi—2nd magn.	204 L. Y. (*Baker*)= 1·198 quadrillion m.

Note.—Its surface temperature is 2,850° C.— (*Abbot*). Its diameter is 34,640,000 m.—(*Baker*). Another Giant Sun. In Hindu Astronomy it is the second star in the 25th lunar mansion *Purvābhādrā*.

(50)	*Beta Crucis* — in Constellation Southern Cross — 1st magn.	204 L. Y. = 1·198 quadrillion m.

Note

It is a bright bluish star.

The Constellation Southern Cross is known in Hindu Astronomy as ***Trishanku***, consisting of 7 stars, 2 of which are of 1st magn.

In Hindu mythology, Trishanku was a celebrated monarch of the solar race, king of Ayōdhya and father of the great Harischandra. He was a wise, pious and just ruler, but had one great weakness. He loved his person to an inordinate degree. Desiring to perform a sacrifice by virtue of which he could go to heaven in his mortal body, he requested his family-priest Vashishta to officiate for him. Having met with a refusal, he called upon his hundred sons to do so, but they too declined. The king, in his rage, called them cowards and impotent beings and was in return cursed and degraded by them to be a Chandāla (an outcast). While he was in this wretched condition, Vishvāmitra, whose family Trishanku had in time of famine laid under deep obligation, undertook to perform the sacrifice and invited the gods to be present. They however declined, whereupon the enraged sage, by his own power, lifted Trishanku into the skies with his dearly cherished mortal body. The king soared higher and higher till his head struck against the vault of heaven, whence he was hurled back headlong by Indra and the other gods. The mighty Vishvāmitra however arrested his fall in the sky, saying :— ' Stay, Trishanku', and the unfortunate monarch remained suspended in free space with his head towards the earth as a constellation in the southern hemisphere.

(51)	*Alpha Crucis*—in Constellation Southern Cross — 1st magn.	233 L.Y. (*Baker*)= 1·37 quadrillion m.

Note.—It is also a bright bluish star and is 1,600 times brighter than the sun.

		Approximate distance from the Earth
(52)	*Spica* or Alpha Virginis—in Hindu Astronomy 'Chitrā', the 14th lunar mansion in Zodiacal Constellation Virgo consisting of one star only—1st magn.	233 L.Y. (*Baker*)= 1·37 quadrillion m.

Note.—Another Giant sun. It is a blue-white star 1,500 times as bright as the sun.

(53)	Average Distance of Stars of the 6th magn.	272 L.Y. (*Baker*)= 1·599 quadrillion m.
(54)	*Beta Centauri*—1st magn.	296 L.Y. (*Baker*)= 1·74 quadrillion m.

Note.—Centaur contains 2 stars of the 1st magn., of which Alpha is of 1st magn. only as a double star. Beta Centauri is a blue star 3,000 times brighter than the sun. Its diameter is 9,526,000 m. and surface temperature 21,000° C.—(*Baker*). Another Giant Sun.

(55)	Pleiades, a group in Constellation Taurus—'Krittikā' or 'Bahulikā' in Hindu Astronomy	326 L.Y. = 1·916 quadrillion m.

Note.—The brightest star in Pleiades is Alcyone (3rd magn.), which is 1,000 times as brilliant as the sun.

'Krittikā' is the 3rd lunar mansion in Hindu Astronomy. It consists of 6 stars which, in Hindu mythology, are represented as six nymphs nursing Kārtikéya, the god of war.

(56)	Constellation Perseus ...	350 L.Y. (*Brady*)= 2·058 quadrillion m.
(57)	Average Distance of Stars of the 7th magn.	362 L.Y. (*Baker*)= 2·128 quadrillion m.
(58)	ANTARES or Alpha Scorpionis or Cor Scorpionis (Scorpion's Heart) —'Jyeshtā' in Hindu Astronomy —1st magn.	362 L.Y. (*Baker*)= 2·128 quadrillion m.

Note.—It is a very brilliant star of red colour, with a surface temperature of 3,100° C., and a diameter of 415,680,000 m.—(*Baker*). Another Giant Sun. Antares is the largest star so far discovered. It is 4,000 times as bright as the sun.

Jyeshtā, in Hindu Astronomy, is the 18th lunar mansion consisting of 3 stars.

(59)	Rasalgeti or Alpha Hercules—a coloured double star, one of 3rd magn. of orange colour, and the other of 6th magn. of green colour	408 L. Y. (*Baker*)= 2·399 quadrillion m.

Note.—Its diameter is 346,000,000 m.—(*Jeans* and *Baker*). Another Giant Sun. Its surface temperature is 2,500° C.—(*Abbot*).

(60)	Average Distance of Stars of the 8th magn.	501 L. Y. (*Baker*)= 2·945 quadrillion m.
(61)	*Rigel* or Beta Orionis—'Banarāja' or 'Bharata' or 'Neela' in Hindu Astronomy—1st magn.	543 L. Y. (*Baker*)= 3·192 quadrillion m.

Note.—It is an extraordinarily brilliant blue-white star and is the brightest among stars of the 1st magn., being 15,000 times as bright as the sun. Its surface temperature is 16,000° C., and its diameter is 18,000,000 m. by radiometer.–(*Abbot*). Another Giant Sun.

(62)	Average Distance of Stars in Constellation Orion	600 L. Y. (*Brady*)= 3·528 quadrillion m.
(63)	*Canopus* or Alpha Argus—in southern Constellation Argo Navis —'Agastya' in Hindu Astronomy —1st magn.	652 L. Y. (*Brady*)= 3·833 quadrillion m.

Note.—Another Giant Sun. It is an exceedingly brilliant star, over 10,000 times brighter than the sun. In Hindu mythology, the sage Agastya is represented to be the regent of this star.

(64)	*Deneb* or Alpha Cygni—1st magn.	652 L. Y. (*Baker*) = 3·833 quadrillion m.

Note.—Another Giant Sun, also exceedingly brilliant, being 10,000 times as bright as the sun. It is of white colour.

		Average distance from the Earth
(65)	Stars of the 9th magn. ...	693 L. Y. (*Baker*) = 4·074 quadrillion m.
(66)	Stars of the 10th magn. ...	959 L. Y.(*Baker*)= 5·638 quadrillion m.
(67)	Stars of the 11th magn. ...	1,304 L. Y. (*Baker*) = 7·666 quadrillion m.
(68)	Stars of the 12th magn. ...	1,811 L. Y. (*Baker*) = 10·648 quadrillion m.

Concluding Remarks

From the information given in the foregoing list emerge three features of outstanding interest :—

(1) The apparent huge area in space taken up by the Stellar Creation, as compared with that occupied by the Solar System of which the earth is a member.

(2) The unimaginably vast distances from our globe at which stars dwell.

(3) The staggering sizes of a number of stars called Giant Suns.

We are told by Jeans, as has already been mentioned, that the gigantic 100-inch telescope at Mt. Wilson has revealed the existence of about a billion and a half stars. He estimates their total number in the universe at over 100 billion. The question may be asked :— 'Is not space overcrowded by these countless hosts ?' A ready and convincing answer is supplied by a high authority in the form of another question :—'Were the Mediterranean Sea inhabited by only a few hundred fishes instead of by incalculable numbers, could that sea be said to be overcrowded by fish ?' The Stellar System is about 300,000 light-years or 1·7625 quintillion miles in diameter.

It will have been noticed that in some cases two stars, though belonging to the same constellation, are separated from each other by enormous distances. For example, Alpha and Beta Geminorum lie 62 trillion miles apart, Alpha and Beta Crucis 172 trillion miles, Alpha and Epsilon Eridani 327 trillion, Alpha and Beta Centauri 1 quadrillion and 715 trillion, Betelgeuse and Rigel in Orion 2 quadrillion and 64 trillion, Alpha and Eta Hercules 2 quadrillion and 167 trillion, and lastly, Alpha and 61 Cygni 3 quadrillion and 769 trillion miles !

We now come to the most interesting and impressive feature of the stellar creation, *viz.*, the sizes of the gigantic stars or Giant Suns. From Abbot's book, *The Earth and the Stars*, we find that the total number of such stars discovered up to 1925 was about 800. We shall now proceed to give a fuller idea of the sizes of those Giant and Super-giant Suns whose diameters we have been able to trace.

Name of Star	Number of times larger than the Sun	Times larger than the Earth
Altair (a faint-white giant) —*Shravana*	2·75	3·6 million
Sirius (a white giant) —*Lubdhaka*	5·8	7·63 "
Procyon (a pale-yellow giant) —'Prabhāshaka'	6·8	9 "
Véga (a white giant) —*Abhijit*	13·8	18 "
Algol	29·47	38·56 "
Algol's Faint Companion (a 'dark' giant)	44·22	57·86 "
Regulus —'Maghā'	125	163·5 "
Alpha Leporis, principal star in the southern Constellation Lepus, the Hare, situated directly under Orion. Diameter 7,794,000 m.— (*Chambers's Encycl., 1925-27*)	729	954 "
Beta Centauri (a blue giant)	1,331	1·74 billion
Capella (a yellowish-white giant) —*Brahmahridaya*	1,728	2·26 "
Rigel (a blue-white giant) —*Bharata*	9,000	11
Eta Draconis (a yellow giant) — Diameter 18,186,000 m.— (*Chambers's Encycl., 1925-27*)	9,261	12·116 "
Arcturus (a red giant) —'Svāti'	27,000	35 "
Aldebaran (a red giant) —'Rôhini'	54,872	79·54 "
Scheat (Beta Pegasi) —'Purvābhādrā'	64,000	84 "
Mu (Greek letter) Geminorum (a red giant) —Diameter 56,290,000 m. —(*Chambers's Encycl., 1925-27*)	274,625	360 "
Betelgeuse (a red giant) —'Ardrā'— variable in diameter	19 million to 27 "	24·8 trillion to 35·4 "
Mira or Omicron Ceti (a red giant)	27 "	35·4 "
Rasalgeti or Alpha Hercules, a double star, one of orange and the other of green colour	63·78 "	83·44 "
Antares (a red giant) —'Jyéshtā'	110·59 "	143·68 "

Imagination reels at the stupendous sizes of these Titans of the Universe. As we contemplate them, many of us will be reminded of the poet's lines so familiar to every schoolboy and schoolgirl :—

'Twinkle, twinkle, *little* star,
How I wonder what you are',

while the smallest star, Van Maanen's Star, is possibly of about the same size as the earth, and the largest-known 143 trillion times bigger than our globe. 'Jyéshta' in Sanskrit means 'first', 'chief', 'seniormost' or 'pre-eminent', and Jyéshtā is a most appropriate name for Antares, the biggest Colossus of the Stellar System.

The smallest-known stars are the 'white dwarfs'. Red giants are those whose surface is at red heat, and white dwarfs those whose surface is at white heat. Occasionally a giant star has a very small companion. We are told by Jeans that the red super-giant Omicron Ceti (Mira 'the Wonderful') has been found to have a faint companion, a white dwarf. Jeans has a simple, inimitable style of expression, at times humorous, which should carry conviction even to a child. 'If the stars had a sense of humour,' he remarks in a special article in *Hindu Illustrated Weekly*, referring to what looks like an unnatural association between this 'giant' and the 'dwarf', 'this ill-assorted pair ought to create some merriment by their absurd incongruity and inequality of size. Landseer's "Dignity and Impudence" is quite outdone ; it is as though an elephant and a sandfly were to join hands and travel together through space.' Let it not be forgotten, however, that such a description has reference only to the relative sizes of the two stars, for this 'sandfly' may approach or even exceed the earth in size. A somewhat similar instance of unnatural companionship is found on the earth itself. The pilot-fish, a small creature about a foot long, accompanies large sharks which vary from 36 to over 60 feet in length. It be may added, in passing, that it frequently follows ships for weeks and even months together. Sailors imagine that the pilot-fish guides the ravenous animal to its food, and hence its name, though naturalists think that its real object must be to pick up morsels of food unworthy of the shark's notice. In that case its object in following ships must be to pick up leavings of food thrown overboard.

But in spite of the phenomenal sizes of the giant stars, their masses are comparatively very small. According to Baker, the

masses of the great majority of stars range from 0·2 to 5 times that of the sun. Jeans says that probably very few stars weigh as little as a tenth of the sun's weight.

Let us now 'put into the scales' some of these remarkable objects and take the readings :—

Name of Star	Times the Sun's Mass	Times the Earth's Weight	Weight in tons
Sirius *B*	0·85 (*Jeans*)	282,157	1·86 *octillion*
Alpha Centauri *B*	0·97 ,,	321,991	2·12 ,,
Alpha Centauri *A*.— *Mitra*	1·14 ,,	378,423	2·5 ,,
Procyon *A* — 'Prabhāshaka'	1·24 ,,	411,618	2·7 ,,
Sirius *A* — *Lubdhaka*	2·45 ,,	813,277	5·36 ,,
Capella *A* (brighter component) — *Brahmahridaya*	4·2 (*Baker*)	1,394,190	9·2 ,,
Mira (Omicron Ceti)	5 ,,	1,659,750	10·9 ,,
Antares — 'Jyéshtā'	18·88	6,267,216	41·3 ,,
N. B.—Baker gives the mean density of the substance of this star as 3/10-millionths of the density of water, and the values given here are worked out on this basis.			
Betelgeuse — 'Ardrā'	19·6	6,506,220	42·9 ,,
N. B.—The mean density of the material of this star is given as 1/1500th of the density of air at sea level. The values shown here are calculated on this basis and on the basis of the mean diameter of the star which has been taken to work out its volume.			
Plaskett *B*	63 (*Jeans*)	20,912,850	137·9 ,,
Plaskett A	75 ,,	24,896,250	164·16 ,,

The heaviest star known is thus 75 times heavier than the sun. One writer remarks that stars of a mass outside the limit of 50 times that of the sun cannot possibly exist as they would burst of their very bulk. But in view of the discovery in regard to Plaskett, this limit must be raised to somewhere above 75 times the sun's mass.

According to Jeans, the superficial temperatures of the hottest stars may be as high as 70,000^0 F., *i.e.*, over 38,000^0 C., the interior temperatures must be from 115,000^0 to 29 million deg. C. and the temperatures at the cores of the densest stars 58 million to 290 million deg. C.! Even with regard to temperatures of 30 to 60 million deg. C., the values are so appalling that it is almost impossible to conceive what such an amount of heat means. Jeans gives a graphic idea of it :–

> 'Let us, in imagination, keep a cubic millimetre of ordinary matter—a piece the size of an ordinary pin-head—at a temperature of 50 million deg., the approximate temperature at the centre of the sun. Incredible though it may seem, merely to maintain this pin-head of matter at such a temperature— *i.e.*, to replenish the energy it loses by radiation from its six faces—will need all the energy generated by an engine of 3,000 million horse-power; the pin-head of matter would emit enough heat to kill any one who ventured within a thousand miles of it.'

Of stars of 1st magnitude, the three brightest with a luminosity 10,000 times as much as the sun's or more, are, as already mentioned, Deneb, Canopus and Rigel, whose light is respectively of 32·3 nonillion, over 32·3 nonillion, and 48·45 nonillion candle-power! Speaking generally, the heavier the stars, the more luminous they are, but their luminosity is considerably greater in proportion to their weight. According to a simple empirical formula, the luminosity of stars is just proportional to the cubes of their masses. But we learn from Jeans that there are exceptions where the luminosity is immensely disproportionate to the weight. Thus Sirius *B* is 2·9 times heavier then Sirius *A*, but is 10,000 times more luminous. Procyon has a companion whose weight is only 3·2 times that of the main star, but its luminosity is 180,000 times as much, so that it is very nearly a million times as luminous as the sun. The luminosity of Sirius *B* is thus 850 nonillion, and that of Procyon's companion 2·2 decillion candle-power! Procyon *B* would thus appear to be the most luminous of all the stars yet discovered.

Stars are thus the most interesting bodies in the whole host of heaven. 'The contemplation of celestial things', remarks Cicero, 'will make a man both speak and think more sublimely and magnificently when he descends to human affairs.' The glory of the sun and the moon and of the wonderful panorama of a clear night sky has been sung by poets in all ages and in all climes and is so beautifully, though tersely, expressed by India's great poet-saint, Kabir:—

> 'The Hidden Banner is planted in the temple of the sky; there the blue canopy, decked with the moon and set with bright jewels, is spread. There the light of the sun and the moon is shining; *still* your mind to silence before that splendour. Kabir says, "he who has drunk of this nectar wonders like one who is mad."'

The contemplative mind perceives the Finger of God in the vault of heaven more than anywhere else in the universe. Thomson sings in ecstasy:—

> 'How can I gaze upon yon sparkling vault,
> And view the planets rolling in their spheres,
> Yet be an atheist? Can I see those stars,
> And think of others far beyond my ken,
> Yet want conviction of Creating Power?
> What but a Being of immense perfection
> Could, through unbounded spaces, thus dispose
> Such numerous bodies, all presumptive worlds?
> The undesigning hand of giddy Chance
> Could never fill, with globes so vast, so bright,
> That lofty conclave!'

CHAPTER XVII

The Upper-Stellar and Nebular Region

'Our earth is a tiny appendage to one, and a rather inconspicuous one, of this vast multitude of stars. . . . . . We begin to see now how insignificant our home in space really is: if humility is a virtue to be encouraged, the study of astronomy can do much to inculcate it.'

—*Sir James Jeans*

We have divided the Stellar Region into two parts, the *Lower* and the *Upper* (in the sense of 'Nearer' and 'Farther' respectively), as it is more convenient and appropriate to deal with Star Clusters along with the Nebulae and to consider them separately from the main stars and the constellations dealt with in the last chapter.

Star Clusters and *Nebulae* are two remarkable classes of celestial bodies. The former are vast collections of stars grouped into what are called Clusters. Sometimes a cluster consists of an enormous number of stars, sometimes of coloured stars of great brilliancy, sometimes the stars are grouped in a striking form, sometimes the shining points are so close together that it is impossible to distinguish the rays of the individual stars, and sometimes the stars are so tiny or remote, as in the case of the cluster in the Constellation of Hercules, that it is difficult to distinguish the cluster from a Nebula. In some clusters the separate stars are visible to the naked eye, though only as globular cloudlets of faint light, the best-known being the Pleiades in the Zodiacal Constellation of Taurus. Most of them, however, can be resolved only in a large telescope. Viewed through it, they are revealed in all their grandeur. Some clusters have been found to be vast aggregations of variable stars.

Among the clusters remarkable for their richness and the brilliancy of the individual stars, may be mentioned those in the Constellation of Perseus, that part of it which

is called its Sword-handle, and those in the *Milky Way* (described later) near the Southern Cross. The latter, of course, are invisible from the northern hemisphere. The most beautiful cluster in the northern heavens is the one in Hercules, which contains thousands of stars concentrated in a very small area.

Nebulae are faint cloudy spots or stains of light on the dark background of the sky, immersed in the depths of space. Unlike clouds, which shine by the light of the sun, Nebulae, when well developed, are self-luminous like the stars. They consist mainly of glowing gases of extreme tenuity, hydrogen and helium having been detected in some of them. When far away from the sun, Nebulae look like comets or star clusters. But unlike comets, which move about in the sky, Nebulae remain fixed. A cluster is resolvable into separate stars in a telescope, while a Nebula cannot be so resolved by the most powerful telescope in existence. Nebulae exist in three different shapes—circular or annular, elliptical and spiral. About 8,000 Spiral Nebulae, each believed to be a universe by itself, have been so far discovered. The total number of these 'island universes' is estimated by Dr. Edwin P. Hubble of Mount Wilson Observatory at 10 million.

Nebulae are believed to be the birthplace of stars. The circular ones exist in two forms: spherical and flattened. The former appear like fluffy balls of gas or clouds of fine light particles. These are yet in the early stages of development and no stars are observable in them. It is only when they have assumed a highly flat shape that stars begin to form in them. They are first evolved at the outer regions of the Nebulae, and the more flattened the Nebulae become, the larger is the number of stars present in them, until at last the central core also is occupied by a multitude of stars. So from a light, featureless globe of gaseous matter the Nebula grows to become in the fulness of time an immense star-land. It is 'highly probable that the stars come into existence through nebulous masses of gas

condensing into detached blobs—much as a cloud of steam condenses into drops of water', says Jeans in an instructive article on 'The Origin of the Universe' in the *Hindu Illustrated Weekly* of 16th August 1931. He concludes his explanations as follows:—

'Let us look backwards in time, and try to review the past history of our sun. At first we see it merely as a fluffier, a larger, and a more luminous globe than now. We can look still further back to the time when it is not a star at all, but a still more fluffy blob of gas, mixed up with thousands of others in a nebula of fuzzy gas—the nebula destined ultimately to condense into our star-city. And the rest of space is also occupied by other gaseous nebulae which in the course of time will form other star-cities.

'We can look even further back in time, although only rather conjecturally. Imagine that, at the beginning of time, the whole substance of the universe was scattered through space in the form of gas, this gas being distributed through space as uniformly as the air we breathe is distributed in a large hall or cathedral. It can be proved that the gas would not stay spread uniformly through space in this way. Just as a cloud of gas condenses into stars, this cloud of gas would soon begin to condense into detached blobs.

'Again we can calculate how much gas would go to each ball. And the result of the calculation is significant. We find that each ball would contain just about as much gas as the nebulae we believe are destined to form star-cities.

'Thus it looks probable that the matter of the universe started as a gas uniformly diffused through space, and this gas condensed, as it would have to, into distinct detached blobs, which are the present nebulae. If this conjecture is sound, we can piece together the story of the evolution of the universe.'

Those Nebulae which lie in or near the plane of the Milky way are called Galactic Nebulae, and those which exist outside this plane are known as Extra-galactic Nebulae.

The light that comes from the nearest globular cluster of stars began its long journey across space towards the close of the first half of the Stone Age, that is, in the glacial period in the geologic time-scale, when the Védic Aryans, if we accept Tilak's theory, lived comfortably in their Arctic homeland near the North Pole, while the light which comes to us from the nearest Spiral Nebula started on its voyage in the Tertiary Epoch or the Age of Mammals, that is to say, before the creation of Man !

The sizes of Nebulae are far in excess of that of the sun or of the largest of stars. Most of those known are millions of times larger than the entire solar system.

Even so gigantic a body as the Nebula has not escaped the astronomer's scale-pan ! We are told by Jeans that the average Nebula weighs two or three billion times as much as the sun. Even on the basis of the lower of these two values, we find that this weight amounts to the staggering figure of 4,377,094,000,000,000,000,000,000,000,000,000,000 or over 4,000 decillion tons !

	Approximate distance from the Earth
(1) Inner Border of the *Milky Way* or *the Galaxy—Nabhassarit* in Hindu Astronomy, or 'Akāsha Gangā' (the Celestial Ganges) as it is called in the Marāthi language	4,000 L. Y. (*Hugo Sleeger*) = 24 quadrillion m.

Note.—The Milky Way is a broad band or girdle of faint light sweeping round the heavens like a gigantic arch and consisting of millions of stars grouped in clusters, some remarkable for their brilliancy and others for the vast number of stars contained in them. The stars are generally so closely packed that the whole assemblage looks like a track or stream of faint 'milky' light. Milton describes it in *Paradise Lost:*—

> 'A broad and ample road, whose dust is gold
> And pavement stars, as stars to thee appear,
> Seen in the galaxy—that Milky Way
> Thick, nightly, as a circling zone, thou seest
> Powdered with stars,'

The Milky Way is a universe of stars by itself. It is called the Galactic System, and our solar system belongs to it.

The above distance is that given by Dr. Hugo Sleeger, Director of the Munich Observatory, Bavaria.

		Approximate distance from the Earth
(2)	Stars in the Milky Way ...	4,250–5,000 L.Y. = 25-29 quadrillion m.

Note.— More than 90 million stars or 6 per cent of the total number so far discovered in the whole universe lie in the Milky Way.

(3)	External Border of the Milky Way	9,300 L. Y. (*Sleeger*) = 55 quadrillion m.
(4)	Nearest Globular Cluster of Stars	21,000 L. Y. = 123 quadrillion m.
(5)	*Messier 13*, a famous Star Cluster in Constellation Hercules	35,000 L. Y. (*Shapley*) ± 206 quadrillion m.

Note.— This group contains nearly 50,000 stars, the smaller of which have been found to be 100 times and the larger 1,000 times as large as the sun!

(6)	NUCLEUS OR CENTRE OF THE ASTRONOMICAL UNIVERSE, about which, according to Shapley, it is whirling in space with its billions of stars including the brilliant Giant Suns and other luminous celestial bodies and the Nebulae, like a gigantic illuminated disc wheel .	65,000 L.Y. (*Shapley*) = 382 quadrillion miles

Note.— This central hub about which the wheel of the Astronomical Universe is said to be spinning, is estimated by Shapley to be 29,000 *L. Y.* (170 quadrillion miles) across and 16,000 *L. Y.* (94 quadrillion miles) thick, and situated in the direction of the Zodiacal Constellation of Sagittarius. He is careful to explain, however, that this nucleus is the centre of only that universe with which astronomical science is familiar and which it can measure at the present time; in other words, the centre of one particular visible and comprehensible universe which forms our galaxy, and not the centre of centres of the entire Stellar Creation.

		Approximate distance from the Earth
(7)	*Nubecula Minor* or Lesser Magellanic Cloud	104,320 L. Y. (*Baker*) = 613 quadrillion m.

Note.—Magellanic Clouds are two conspicuous whitish Nebulae of a cloud-like appearance near the South Pole. They are visible to the unaided eye. The maximum diameter of the Lesser Cloud is 6,520 L. Y. (*Baker*) or 38 quadrillion m.

(8)	*Nubecula Major* or Larger Magellanic Cloud	110,840 L. Y. (*Baker*) = 651 quadrillion m.

Note.—Its greatest diameter is 14,018 L. Y. (*Baker*) or 82 quadrillion m.

(9)	Farthest Globular Clusters of Stars yet discovered	220,000 L. Y. (*Jeans*) = 1·29 quintillion m.
(10)	*Messier 31*, the Giant Spiral Nebula in the Constellation of Andromeda	800,000 L. Y. (*Hubble*) = 4·7 quintillion m.

Note.—According to Dr. Russell, the diameter of this great Nebula is 40,000 L. Y. (235 quadrillion m.). It is the only Spiral Nebula that can be clearly seen without the aid of a telescope. In fact, it is the remotest heavenly body visible to the naked eye. Its mass as estimated by Russell is about 3 billion times the sun's. The weight of this Nebula will therefore be about 6,565 decillion tons! Its luminosity, says Jeans, is 660 million times the sun's, that is to say, over 2,100 decillion candle-power!

(11)	Nebulae in the Constellations of Coma and Virgo	10 million L.Y.(*Shapley*) = 59 quintillion m.
(12)	Nebulae in the Constellation of Centaurus	100 million L.Y. (*Shapley*) = 587·5 quintillion m.
(13)	Farthest Distance at which Nebulae have been revealed	140 million L. Y. = 822·5 quintillion m.

Note.—Spiral Nebulae at this vast distance have been discovered by Hubble, probably the greatest space-sounding expert of the day.

We learn from Russell that the brightest stars in the Magellanic Clouds show a brightness (photographic) ranging from about 30,000 to 50,000 times that of the sun. Jeans mentions a star in the

Lesser Magellanic Cloud named S Doradus whose average luminosity is over 300,000 times and maximum over half a million times the luminosity of the sun, so that, at its brightest, its light will amount to more than 1·6 decillion candle-power! *S* Doradus is therefore the most luminous star discovered, next to Procyon *B*. Hubble, says Russell, estimates that on the average the Nebulae are 15,000 times as bright (photographically) as the separate stars that can be seen in them, and that the faintest Nebula gives out 60 million times, the typical Nebula 600 million, the Andromeda Nebula 1 billion and the brightest 6 billion times the sun's light!

Concluding Remarks

It will have been noticed from the foregoing items that the stellar universe to which we belong is far from being the largest system in existence. In his book, *Flight from Chaos*, Shapley endeavours to classify the various types of material bodies and systems and to arrange them in the ascending order of size. The book bears the sub-title 'A Survey of Material Systems from Atoms to Galaxies', a feat attempted for the first time in the history of science.

'There is', he says, 'no avoiding electrons, whose diameters are a millionth of a millionth of a millionth of a mile when we measure the galactic system, whose diameter is a million million million miles. We need to consider the behaviour of the individual radiating mechanism consisting of one atom, when we analyze the behaviour of an individual radiating star', which is built up of countless atoms.

The minutest system is the *atom*. It has been computed that the tiniest speck of matter visible through a powerful microscope has an actual diameter of 1/100000th of an inch and that this speck is built up of more than 125 million atoms! And yet the atom is itself a miniature universe and is a structure made up of smaller particles. It is composed of *electrons*—particles charged with negative electricity—and *protons*, the positive charges. A little further idea of this remarkable structure may be found interesting. The diameter and weight of an electron are inconceivably small. Something like 6,350 billion electrons are required to cover a length of one inch, or about 25,000 particles to approach the length of the

shortest X-ray waves, or again, 32 million to reach the length of the shortest waves of ultra-violet light which themselves measure ·000005 inch! A string of 72 septillion electrons covering a length of 16 trillion miles or two-thirds the way to the nearest star, will weigh only one grain troy! The proton is believed to be much smaller than the electron, though it is 1,845 times heavier. The hydrogen atom is built up of a single electron and a nucleus which consists of a single proton, but in all the other elements the number of electrons present ranges from 4 to 200 or more, and the nuclei are compact, massive structures in which protons as well as electrons are present. The protons in these cases outnumber the inner electrons, so that, in the result, the nucleus remains a positive charge. The outer electrons revolve at a distance around the nucleus in circular or elliptical orbits through the attraction exerted by the nucleus, as the planets do round the sun, and they fly at furious speeds. These are called *orbital* or *planetary* electrons, and the inner ones packed with the protons are called *nuclear* electrons. The helium atom consists of 4 electrons, 2 nuclear and 2 orbital, and 4 protons. The mercury atom is built up of 80 orbital and 120 nuclear electrons and 200 protons. But the element whose atom contains the largest number of protons and orbital electrons is uranium, the heaviest of all the elements so far discovered. It has 92 orbital electrons. As it is the proton that really gives the atom its weight, the atom of uranium necessarily contains a larger number of protons than does the mercury atom — very nearly 238. The electron takes up no more space in the atom than does a planet in the solar system. 'The greater part of the atom is space', remarks the great physicist Sir Oliver Lodge, and by way of illustration he adds:– 'If the void in the atoms composing our bodies were done away with and the solid residue pressed together, our dimensions would be microscopic'! Atoms vary in size and weight according to the chemical element to which they belong, but the differences in size are considerably less marked than the differences in weight. About 36 sextillion atoms of hydrogen weigh only one grain troy, while only 2·4 sextillion atoms of oxygen are wanted to make up this weight.

After the atomic system follow the molecular systems, crystalloids and colloids, under which category fall living organisms inclu-

ding the human body. A brief idea may be given of the smallness of a molecule. About 100 million molecules in general, and in the case of water 55 million, are needed to cover the length of one inch. A single drop of water contains something like 2·625 septillion of them. As Jeans graphically puts it, if the molecules contained in a pint of water were placed end to end, they would form a chain that could encircle the earth over 200 million times, and if they were scattered over the whole land surface of the globe, there would be nearly 100 million molecules to every square inch of land!

The atomic and molecular systems thus rank lowest of all in the size scale of bodies in the universe, if we except the electrons and protons into which the atoms are partially or entirely split at the centres of the sun and the stars and some of which escape into space.

Next follow the crystals and colloids, and then farther up in the scale come the groups of meteorites, and satellitic systems such as the Earth's Moon and Jupiter's satellites. These in turn are followed by planetary structures, which are divided into three classes: stars with coronae and meteors, the solar system, and stars enveloped in nebulae. Next in order are the double and multiple stars, the galactic clusters and globular clusters of stars. Still higher in the scale are the galaxies, of which the 'local system', whereof the sun is a member, the Milky Way and the Magellanic Clouds are examples. The spiral nebulae are also classed as galaxies. A system of galaxies is termed a *super-galaxy*. The whole group of super-galaxies, numbering millions, constitutes the *metagalaxy*, whose diameter is estimated at billions of light-years.

'There is evidence', continues Shapley, 'that a rough uniformity in the frequency of galaxies is maintained throughout all space within our reach, but our telescopes have not yet struck bottom. They do not indicate that we are even approaching the borders of the system. The metagalaxy must remain for the present as the vague super-system—all-comprehensive, but incomprehensible.'

The metagalactic system, we are reminded, does not make up the entire universe. Outside the system are the 'random stars' or 'lost planets', wandering meteors or detached atoms and electrons and interstellar gases. 'The greatest unsolved mysteries of the physical world probably lie in this realm of unorganized or dimly

organized particles and corpuscles that move speedily, and perhaps endlessly, through intergalactic space.' Shapley suggests the name of 'Cosmoplasma' for this 'vague substratum', which is the gathering ocean of the radiant energy of the sun and stars. Are fresh masses of stars being formed in this vague region? Jeans and other distinguished scientists hold the view that the energy of the universe is running down, the ultimate result of which is universal death. But Shapley thinks rather differently. 'Cannot the expended radiation', he asks, "re-form into corpuscles, atoms, molecules, and eventually nebulae, and stars, replacing fading stars with fresher universes?' At the same time he cautiously adds that it is safer to ask such questions than attempt to answer them!

Dr. James Chadwick, for many years an assistant of the famous physicist, Lord Rutherford, at Manchester and now Assistant Director of Research in Radio-activity at the Cavendish Laboratory, Cambridge, has discovered a new smaller system than the atom. It is called the *neutron*. Its existence had been predicted by Lord Rutherford in 1920. A fair amount of literature about it has already appeared in the Press. The neutron is described as consisting, like the hydrogen atom, of a proton and an electron with this difference that in the latter there is a relatively big gap between the two particles so that they are loosely held together, while in the former they are closely bound together and *carry no electric charge*, whence the name *neutron*. And yet in a sense the neutron may be regarded as hydrogen in the embryonic stage, for if it were possible to draw its particles wide apart from each other, the result would be a hydrogen atom. The neutron could well be the first stage in the combination of the two ultimate particles in the building up of all matter in the universe. The study of the neutron by itself is exceedingly difficult. It is possible to keep hydrogen under pressure in a vessel, but it has so far been found impossible to confine neutrons. They easily slip through glass, metal or rubber. Their extraordinarily penetrative power is due to the fact that they are of extremely small size and owing to the absence of an electric charge in them are not repelled by charged atoms which they approach. Their velocity is computed at 10,000 miles a second. Their range in air is more than a mile, and they will pass through great thickness of lead. The effective stop-

ping area of a layer of matter is to them considerably smaller than to an electron or proton, so that they may be able, to force their way through the interstices of the atoms of matter much more successfully than protons or electrons. The penetrating power of neutrons is so high that one writer says that, if a cannon-ball could be made of them, it would pierce 75 million miles of armour! The neutron is expected to provide a new and powerful weapon in attacking the atom.

CHAPTER XVIII

The 'Giant Cranes' of the Universe

The reader will have guessed from the strange heading of this chapter that these 'cranes' are none but the few giant telescopes of the world. It is not out of place briefly to describe here the principle of this instrument so essential and invaluable in astronomical study and research, and the various stages of its development since its invention over three centuries ago.

The human eye admits just so much light as falls on a circle whose radius amounts to the tenth of an inch. Defective hearing is overcome by the use of the ear-trumpet, which gathers in sound waves and throws them on to the tympanum. Similarly, the power of vision can be increased by gathering the rays of light falling on a wide area and refracting them so that they penetrate through the pupil of the eye and reach that fine network of optic nerves called the retina. It is on this principle that the telescope is built. It is stated that the world's first working telescope was constructed in 1608 by Lippershay, a Flemish spectacle-maker. In the following year Galileo built a small instrument with an aperture of 2¼ inches. It is to these humble beginnings that the world owes its present knowledge of the wonders of modern astronomy.

Galileo's telescope meant a very considerable increase in man's range of observation. The first big advance was made in 1789, when Sir William Herschel constructed a 48-inch instrument. This telescope collected upwards of 400 times as much light as Galileo's, and more than 50,000 times as much as the naked eye. The next high stage was reached with the construction of Lord Rosse's 72-inch telescope in 1845. Years passed, and 1916 saw the installation of a telescope of the reflecting type with a

72·5-inch mirror in the Dominion of Canada Astrophysical Observatory at Victoria, British Columbia. It is operated by electricity. Four years later came another great advance, for 1920 saw the erection of the giant Hooker instrument with its 100-inch aperture at Mt. Wilson Observatory in California. It weighs 100 tons. Long before this time the use of the human eye for observation purposes had been dispensed with. The retina can retain light for only a fraction of a second, and it was replaced by the photographic plate, which can record the whole amount of light received for several nights in succession. The Hooker instrument not only collects 250,000 times as much light as the human eye, but it throws it on to the highly sensitive photographic plate.

In 1929 another large reflector telescope was erected in America, the biggest ever made in that country. The Perkins Observatory at Delaware, Ohio, where it is installed, has since July 1931 been thrown open to students at the local Wesleyan University, for it was intended by the founder of the observatory primarily for the benefit of these students. This telescope is the first instrument of its size to be dedicated mainly for the use of University students. It is said that its 69-inch mirror is free from the slight imperfections that mar to some extent the 100-inch reflector at Mt. Wilson and the 72·5-inch telescope at Victoria. It is therefore claimed to be as powerful and effective as these two giants.

Canada will shortly have another large reflector telescope. It is under construction in England and is expected to be ready before the end of 1933. In instruments of this type a concave mirror is used instead of a lens, and the mirror of this new telescope will have a clear aperture of 74 inches, being fashioned from a disc of glass 76 inches in diameter and 12 inches thick. The telescope will be housed in a huge observatory to be built near Richmond Hill, Toronto District, which on completion will be presented to the University of Toronto.

The 100-inch telescope is the largest in the world at present, but it will soon be eclipsed by a new one, also of the reflector type, to be erected at Pasadena and is expected to be ready for use in the near future. It is described as a marvel of engineering. This 'super-telescope' marks as great an advance over the present largest instrument as the latter did over Herschel's. It will gather in four times as much light as the 100-inch telescope and will reveal celestial objects that are twice as far away as similar objects now visible.

The principal disadvantage of a telescope of the present type of reflector has been its sensitiveness to varying temperatures. Even a slight change in the surrounding temperature will expand or contract the glass, a process which gives a distorted picture of the heavenly body under observation. It is believed that this difficulty will be solved in the super-telescope by the use of a disc of fused quartz in place of glass for the great mirror, as the new substance can withstand fluctuations in temperature much better. It is estimated that this mirror alone will weigh 30 tons! The fused quartz disc is expected to enable astronomers to study the sun direct, which has never yet been possible with a reflector, and to wrest fresh secrets out of our great luminary. As the new telescope will have a light-gathering power four times that of the present 100-inch one or a million times greater than the naked eye, it is hoped that it may at last furnish definite evidence about the fascinating possibility of human life on any of the other planets.

Considering the progress made in the construction of large telescopes within the last few decades, the time is bound to come when instruments bigger than even the forthcoming 200-inch giant become an accomplished fact. Dr. G. W. Ritchey, the famous American designer and builder of large astronomical telescopes, considers that, with the accumulated experience and modern engineering skill, it ought not to be difficult to build an 8-metre (315-inch) super-telescope and that the next stage thereafter ought to

be reached in a quarter of a century when the 8-metre giant will pass into the second rank with the construction of another super-telescope, a 24-metre (945-inch) giant!* We shall then have a titanic 'crane' able to strain its neck and penetrate nearly a billion and a half light-years or over 8 sextillion miles into the vast abysses of space!

It was reported in *Popular Mechanics Magazine* of June 1931 that a new high-speed lens weighing less than 2 lbs. had been manufactured by Mr. W. B. Rayton, head of the Bausch & Lomb Optical Co., and sent to the California Institute of Technology. It was originally meant for future use on the 200-inch telescope, but the astronomers at Mt. Wilson gave it a trial on their 100-inch instrument. It is said that the lens at once transformed the latter into a 200-inch instrument for all practical purposes and that research work which had to be postponed till the installation of the monster telescope was forthwith taken up. It is claimed that, with the Rayton lens, the power of all large telescopes in existence can be doubled at a cost of only a few hundred dollars, as against millions required for the construction of larger telescopes.

* Detailed information on the subject will be found in an exhaustive article by Ritchey in *L'Illustration*, the famous French weekly, of 22nd February 1930, under the caption 'A la Recherche des Mondes Inconnus—La Grande Aventure' ('In Quest of Unknown Worlds—The Great Venture').

CHAPTER XIX

Outer Space

In the last chapter have been given brief descriptions of the largest telescopes in the world. The monster eyes of the 'giant crane' of 1932 will penetrate into the depths of space to a distance of about 300 million light-years, *i.e.*, 1,763,400,000,000,000,000,000 or in round figures 2 sextillion miles. While the 100-inch instrument shows about 2 million Nebulae, the new 200-inch telescope is expected to reveal about 14 million more, besides a vast universe of faint stars, half a billion or so, which lie outside the range of the most powerful instruments in existence. It will thus be able to take a census many times wider of the countless hosts that populate the farther regions of heaven.

What may be the physical state of space at these fabulous distances from the earth? Some idea of its extent of emptiness will be gained from the fact that, according to the tabulation of densities in various parts of the Universe made by the Eastman Kodak Research Laboratory, the atoms even in interstellar space are more than a quintillion times scarcer than in ordinary air. And what may be the temperatures there? Even as regards conditions at distances vastly smaller in comparison, Jeans says:—

> 'A thermometer placed out in interstellar space, far from any star, would probably show a temperature of only about 4^0 above Absolute zero, while still lower temperatures must ~~be reached~~ out beyond the limits of the galactic system.'

Now 4^0 above Absolute zero means -269^0 C.($-452{\cdot}2^0$ F.), a point at which no gas known to science can remain in its natural state and which is only the tenth of a degree C. below the point where helium, the most refractory of gases, turns liquid. At such a temperature mercury would freeze so hard that a hammer-head could be made

of it to drive a nail! Liquid helium is so cold that it boils even more furiously than does liquid air or liquid hydrogen when dropped on a cake of ice. If yet lower temperatures obtain beyond the limits of the Milky Way, the lowest temperature in Outer Space, if not Absolute zero, may be at most a degree above it, so that, if the earth's atmosphere could be transported to the coldest parts of this remote region, it would freeze straight away, not a single gas escaping this fate!

Can so chilling a temperature be produced in the laboratory? The answer was supplied in 1926 when the Dutch scientist, Dr. W. H. Keesom, Director of the Cyrogenic Laboratory at Leyden, solidified helium at -271·9° C. (-457·4°F.), thus almost reaching the rock bottom of the temperature scale and achieving one of the most brilliant feats of science.

CHAPTER XX

The 'Vault' of Space or 'Roof' of the Universe

In the course of an article on 'Time, Space and Relativity' in *Science and Invention* of April 1929, Dr. Menzel says that, if we describe from a point on the earth a series of circles, the radius of the first being 1 centimetre (0·3937 inch), and the radii of the subsequent circles are doubled each time, the 30th circle will be as large as the earth.* 'The question that enters the mind is,' he proceeds, 'can we keep increasing the size of such circles indefinitely? According to Euclid, with infinite space, the answer is yes. Einstein, however, says no; the 96th circle would be the last one that can be drawn in our universe. Finally, we come to the point where no possible measurement can distinguish between the arc of one of these huge circles and our ideal straight line.' The writer adds that, if we could get into a Jules Verne projectile and travel with the speed of light in the 'straightest line' that could possibly be negotiated, we should really be moving along this 96th circle; in other words, we should be sweeping out a great circle through the universe, ultimately to return to our starting point. This is how he opens his explanation of Einstein's postulate that space is '*finite, yet unbounded*' and is *spherical*—finite because, like the surface of the earth, *space bends back on itself and closes up.*

Sir James Jeans remarks that the astronomer of to-day regards the universe as a finite, closed space, as finite as the surface of the earth, although, of course, it is a space which is three-dimensional, having 'breadth, width and height', *i.e.*, 'a north-south, east-west and height.'

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* The radius of the 30th circle would amount to $\frac{0\cdot3937}{12 \times 5280} \times 2^{29}$ miles = 3,336 miles, which is a little less than the actual radius of the earth, *viz.*, 3,963 miles.

In the course of his presidential address on 'The End of the World' at the Annual Meeting of the Mathematical Association held early in 1931 at Southampton Row, London, Sir Arthur Eddington observed that, if we proceeded in any direction in space, we would not come to an end of space, nor would we continue on to infinity, but, after travelling a certain distance, we would find ourselves back at our starting point. 'We have recently learnt', he said, 'mainly through the work of Professor Lemaître that this spherical space is increasing rather rapidly. In fact, if we wish to travel round the world and get back to our starting point, we shall have to move faster than light, because while we are loitering on the way, the track ahead of us is lengthening. It is trying to run a race in which the finishing tape is moving ahead. . . . .

. . . . . From the astronomical data it appears that the original radius of space was 1,200 million light-years. At that radius, the mutual attraction of matter in the world was just sufficient to hold it together and check the tendency to expand, but this equilibrium was unstable. An expansion began, slow at first, but the more widely the matter was scattered, the less able was the mutual gravitation to check the expansion. We do not know the radius of space to-day, but I should estimate that it is *not less than 10 times the original radius.*' Obviously the term 'world' as used here means the whole universe.

Eddington, it is of course understood, gives even this minimum value as the radius of space as the result of calculations based on such data as are available. The famous Belgian mathematician, Abbé G. Lemaître, suggests, on the basis of 'such rough available data as seem at present plausible' regarding the average density of matter in the universe and also the rate at which space is expanding, that the present radius of space is about 18 billion light-years.

In his famous book, *The Universe Around Us*, Sir James Jeans, in the course of his remarks on this subject, says :—

'From the known weights of these (extra-galactic nebulae), Hubble estimates that the mean density of matter in space must be about 1.5×10^{-31} times that of water. On the assumption that matter is distributed with this density through the whole of space, including those parts which our telescopes have not yet penetrated, we can calculate quite definitely that the radius of space is 84,000 million light years, or 600 times the distance of the farthest visible nebulae. The journey round space would take 500,000 million light years.'

Modern astronomers consider that the centre of the universe lies very far away from the earth, and at a distance which may be calculated in scores of thousands, perhaps hundreds of thousands, of light-years. But this distance, however vast it may appear by itself, is, compared with the probable radius of space, so infinitesimal that, where vast mathematical calculations are concerned, it may be ignored and the earth treated as the actual central hub of the whole universe.'

At a lecture on the 'Inter-action of Life and Matter', Sir Oliver Lodge, after discussing the three stages of matter—solid, liquid and gas, spoke of the even greater importance of space. Ether or space, he said, was believed by some to be substantial, but he expected that it would be found eventually that matter was composed of it. 'The universe is no longer regarded', he explained, 'as particles of matter interrupted by space, but as space interrupted by particles of matter.' Jeans remarks, as already stated, that the astronomer of to-day regards the universe as a finite closed space. From these remarks it is clear that leading scientists consider that space and the universe are co-extensive and coterminous.

Now three different estimates are put forward, two of them tentatively and one as the minimum, by three authorities of world-wide distinction, as the radius of space today. While it is difficult to accept any one of these three values in preference to either of the other two, Eddington's minimum estimate may be accepted for the time being,

as it is the latest to be put forward by a world-scientist. On this basis we find that the Radius of Space, or the Height above Earth of the 'Vault' of Space or 'Roof' of the Universe, is at the present day at least 12 billion light-years or about 70 sextillion miles.

'Certainly, if this is "finitude",' remarks a writer commenting upon one estimate of the radius of space, 'it is a kind of finitude which bludgeons the mind into stupefaction.'

It will thus be noticed that the whole solar system, which includes the earth, is only a tiny island group in this vast ocean of space.

Now this estimated rough height above earth of the 'Roof' of the Universe would be a fixed quantity, only if space remained constant. But we are told that space appears to be expanding. According to Lemaître, it appears to be expanding at the rate of about 1 per cent in every 20 million years, so that it doubles its diameter every 1,400 million years. Jeans too accepts the theory of space-expansion. Eddington tells us that not only does space go on expanding in geometrical progression, but it is expanding rather faster than light can travel. 'Can this expansion go on indefinitely,' asks Lemaître, 'or like a soap-bubble, must space eventually burst?'

About the ultimate fate of the universe Jeans has a remarkable theory :—

'Sooner or later the time must come when the last erg of energy of the universe has reached the lowest rung on the ladder of descending availability, and at this moment the active life of the universe must cease. The energy is still there, but it has lost all capacity for change; it is as little able to work the universe as the water in a flat pond is able to turn a water-wheel. We are left with a dead, although possibly a warm, universe—a "heat-death". Such is the teaching of modern thermodynamics.

. . . .

'The final state of the universe will be attained when every atom which is capable of annihilation has been annihilated, and its energy transformed into heat-energy wandering for ever round

space, and when all the weight of any kind whatever which is capable of being transformed into radiation has been so transformed.'

At his Rede lecture at Cambridge delivered since the publication of his book, Jeans drew attention to the general physical principle known as the Second Law of Thermodynamics, which predicted that there would be but one end to the universe— a 'heat-death', in which the total energy of the universe was uniformly distributed and all the substance of the universe was at the same temperature. This temperature would be so low as to make life impossible and the consequence would be universal death.

But while so much is being said about the end of the universe, the question may be asked what its present age may be. Even this subject has not escaped the attention of modern cosmologists. Calculating from the present weights of the sun and stars and the rates at which they have been losing mass, *i. e.*, annihilating their atoms, and travelling backward to very remote times long before the birth of our planet, an estimate of from 5 to 10 trillion years has been formed as the probable age of the stars in general. But before the birth of the stars their atoms might have previously existed in the Nebulae for a like or possibly longer period. From the fairly accurate weights available of two extra-galactic Nebulae, one of which is the Andromeda Nebula, it is calculated by Jeans that the atoms in this latter body must have an average life-period of 80 trillion years and those in the other Nebula, N. G. C. 4594, which has the weight of 2 billion suns and the luminosity of 260 million suns, a life-period of 115 trillion years. From these two cases he thinks that the average life of the atoms in such Nebulae, that is, their period of existence since birth up to the time of annihilation, must be somewhere around 100 trillion years. Jeans admits, however, that this calculation cannot be claimed to be either very convincing or very accurate, but adds that it furnishes the only evidence available at present as to the probable life

of matter in the nebular state. The rest of the argument will be best given in his own words:—

'Apart from detailed figures, however, it is clear that we cannot go backward in time for ever. Each step back in time involves an increase in the total weight of the matter of the universe, and just as with individual stars, we cannot go so far back that this total weight becomes infinite. Indeed a limit may quite possibly be set by considerations which we have already mentioned. The complete annihilation of all the matter now in the universe would raise the temperature of the earth's surface by the sixth part of a degree; the annihilation of a million times as much matter would raise it by 160°. We cannot admit that as much radiation as this can be wandering about space. The earth's temperature is determined by the amount of radiation it receives from the sun; it adjusts its temperature so that it radiates away just as much energy as it receives. A small correction is required on account of the earth's own radio-activity, but this need not bother us. What would bother us, and would indeed upset the balance entirely, would be the radiation of a million dead universes if this were for ever streaming on to us out of space; in this event the earth's surface would have to rise to a temperature well above that of boiling water before it could restore the balance between the radiation it received and that emitted. In a word, the radiation of a million dead universes would boil our seas, rivers and ourselves. All this makes it clear that the present matter of the universe cannot have existed for ever; indeed we can probably assign an upper limit to its age of, say, some such round number as 200 million million years.'

Against this estimate of 200 trillion years as the upper limit of the age of the universe, Dr. Ernst J. Opik of Tartu University Observatory, Estonia, at a recent lecture in astrophysics at Harvard, U.S.A., announced his estimate to be not much more than 3 billion years. This value represents the maximum age of the earth itself as estimated by Jeffreys, who fixes its minimum age at 1,300 million years. But according to many scientists whose estimate is derived from the radio-active content of the oldest rocks, the

earth's age is of the order of 1,600 million years, and this estimate has recently been confirmed by a Committee of the National Research Council of America. This new estimate leaves a balance of only about 1,400 million years for the birth and evolution of the sun and the stellar and nebular systems of the universe—rather too small a period if these systems have evolved as slowly as we are led to believe by cosmologists. Opik bases his conclusions on analyses of the helium and radium content of meteorites made by Professor Fritz Paneth of the University of Konigsberg in Germany, who obtained values ranging from 100 million to nearly a billion years. Opik finds evidence in support of Paneth's conclusions in the double stars. From a study of their distances and magnitudes Opik is convinced that these bodies have not shrunk much in the lapse of time, which shows that, relatively speaking, the universe must still be in its infancy.

CHAPTER XXI

Space and the Universe: Sir Arthur Eddington's Views

As a matter of interest, may be quoted here some of the views expressed by Eddington on the subject of Space and the Universe. A little repetition will be necessary for a proper understanding of his views.

Eddington says that, from the astronomical data, it appears that the original radius of space was 1,200 million light-years. He proceeds:—

'At that radius the mutual attraction of matter in the world was just sufficient to hold it together and check the tendency to expand, but this equilibrium was unstable. An expansion began, slow at first, but the more widely the matter was scattered, the less able was the mutual gravitation to check the expansion.

. . . .

'We have found it possible to discover a kind of sign-post for Time in the physical world. It is provided by a certain measurable quantity called entropy, which we may conveniently describe as the measure of disorganization of a system. Accordingly, our sign-post for Time resolves itself into the law that disorganization increases from past to future. The test works consistently. It is possible for the disorganization of a system to become complete. The state then reached is called thermodynamic equilibrium.

'But to return to our sign-post. Ahead there is ever increasing disorganization. We notice one strange fact that, although the sum-total of organization is diminishing, certain parts of the universe are exhibiting a new and more highly specialized organization. That is a phenomenon of evolution. But ultimately this must be swallowed up in the advancing tide of chance and chaos, and the whole universe will reach a state of

complete disorganization—a uniform, featureless mass in thermodynamic equilibrium. This is the End of the World.

'Time will extend on and on, presumably to infinity. But there will be no definable sense in which it can be said to go on. Consciousness will obviously have disappeared from the physical world before thermodynamic equilibrium is reached.

'It is more interesting to look in the opposite direction—towards the past. Following Time backwards, we find more and more organization in the world. Surveying our surroundings, we find them to be far from a "fortuitous concourse of atoms". The picture of the world, as drawn in existing physical theories, shows arrangement of the individual elements for which the odds are multillions to one against an origin by chance. Some people would like to call this non-random feature of the world Purpose or Design. I hardly go so far as that: I will call it non-committally anti-chance.'

In conclusion, adds the famous astronomer:—

'It used to be thought that at the end of the world all the matter of the universe would collect into one dense ball at uniform temperature; but the doctrine of spherical space, and more especially the recent results as to the expansion of the universe, have changed that. There are one or two unsettled points which prevent a definite conclusion, so I will content myself with stating one of several possibilities.

'It is widely thought that matter slowly changes into radiation. If so, it would seem that the universe will ultimately become a ball of radiation growing ever larger, the radiation becoming thinner and passing into larger and longer wave-lengths.

'About every 1,500 million years it will double its radius, and its size will go on expanding in this way in geometrical progression for ever.'

From the lines quoted at the head of Chapter XVI it might be inferred that the scientists of Byron's or earlier times anticipated present-day men of science in declaring that the universe goes on expanding for ever! But the great poet uses the term *expansion* in the sense of 'expanse'

or 'immensity', so that a 'universe of endless expansion' should be understood to mean a universe without finitude or limits.

In another address delivered in November 1931 to the Physical Society at the Imperial College of Science and Technology in London, Eddington gave a further notion of the latest ideas of an expanding universe. He said that the most striking thing was that more than 80 galaxies had been observed to be receding from us, moving outwards, and not one had been found coming in to fill the voids. 'It is an obvious inference', he proceeds, 'that in the course of time the region will be evacuated. The nebulae will all be out of reach of our telescopes unless we increase our telescopic power to keep pace. I find that an observer of nebulae will have to double the aperture of his telescope every 1,300 million years merely to keep up with their recession. Sir James Jeans delights in telling us that we have billions of years before us in which to find out all that can be found out about the universe. I suggest, however, that there is urgency as regards the spiral nebulae. If we leave it too late, there will be none left to examine.' He thinks there is little doubt that these recessions are due to the cosmical expansion. 'The circumference of the world is expanding,' he goes on to explain, 'and light is like a runner on an expanding track with the winning-post receding faster than he can run. In the early days light and other radiation went round and round the world until it was absorbed. This merry-go-round lasted during the very early stages of expansion. But when the world had expanded to 1,003 times its original radius, the bell rang for the last lap. Light waves then running will make just one more circuit. Those which started later will never get round. Somewhat later the last half-lap was announced. From that moment onwards it has become impossible for light to travel half-way round. So that corresponding to any star, there is a region of the universe which its present radiation will never reach. And if light cannot reach, no other

casual influence can, for no signal can travel faster than light.'

To make his description still more clear, Eddington compares the universe to an expanding toy balloon, in which he pictures the galaxies of stars as embedded in its inner surface, and as the balloon expands, the stars recede from one another and from the terrestrial globe.

Many other astronomers have apparently accepted the conclusion that the spiral nebulae in the depths of space are receding from us. Their velocities of recession are estimated at from a little less than 1,000 miles to 15,000 miles per second. These velocities for bodies in the universe are certainly very great, for the speed of the earth, for instance, in its revolution round the sun, is only about ~~18~~ miles a second.

CHAPTER XXII

The Weight of the Universe

As stated in Chapter XX, we have accepted for the present Eddington's minimum estimate as to the radius of space, *i. e.*, 12 billion light-years or 70 sextillion miles.

As we are regarding space and the universe as co-extensive and coterminous, we find that the volume of the universe amounts to

$\frac{4}{3} \times \frac{22}{7} \times (70 \text{ sextillion})^3 = 4312 \times 10^{66}$ cubic miles!

We have given in their proper places the probable weights of the Earth, its Crust, its Central Core, its Water and its own and the outer Atmosphere, the weights of the Moon, the Sun, the Planets, Asteroids and Comets, and those of a few Stars and Nebulae. It now remains to ascertain whether it is at all possible to arrive, however roughly, at the probable weight of the *whole* Universe. Looking to the fact that the earth, the atmosphere and all the heavenly bodies and objects occupy an almost negligible total area in the vast ocean of space, the rest of this entity must be composed of matter of extreme tenuity. The average density of the material of the universe must consequently be 'multillions' of times lower than the density of air at sea level.

In Chapter XX have been quoted Jeans's following remarks:—

> 'From the known weights of these (extra-galactic nebulae), Hubble estimated that the mean density of matter in space must be about $1 \cdot 5 \times 10^{-31}$ times that of water. On the assumption that matter is distributed with this density through the whole of space, including those parts which our telescopes have not yet penetrated, we can calculate quite definitely that the radius of space is 84,000 million light years.'

The Right Rev. Dr. E. W. Barnes, Bishop of Birmingham, a mathematician-astronomer of a high order,* in the course of a lecture early in 1931 to the Science Masters' Association at Birmingham University, remarked as follows:—'If we could determine the density of matter in the universe, and also the rate at which it is expanding, we could discover its size. With such rough available data as seem at present plausible, Lemaître has suggested that the radius of the universe is about 18 billion light years.' This remark shows that the density of the material of the universe is still a subject of intelligent mathematical speculation.

As already stated, we have adopted Eddington's minimum estimate for the radius of space, which is one-seventh of that worked out by Jeans. But it is not possible to know whether the former agrees with Hubble's estimate of the density of matter in space. Until, therefore, a fresh value is announced acceptable more widely to leading scientists, we may consider that Hubble's estimate holds the field and accept it, especially as so great an authority as Jeans tentatively adopts it. The density of the universe in terms of that of the earth (which is 5·5 times that of water) will thus be $1{\cdot}5 \times 10^{-31} \times \frac{10}{55}$. Now, adopting this density and the volume of the universe as arrived at already, and knowing the volume and weight of the earth (260 billion cubic miles and 6·593 sextillion tons respectively), we find that the Weight of the Universe amounts to

$$\frac{4312 \times 10^{66}}{260 \times 10^{9}} \times 1{\cdot}5 \times 10^{-31} \times \frac{10}{55} \times 6{\cdot}593 \times 10^{21} = \text{in round}$$

figures, 3,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 or *3 quadrillion decillion tons!*

It must not be forgotten however that there is yet no general agreement among scientists as regards the radius

* Dr. Barnes is a unique example of a divine who is as much at home with the spectroscope and telescope as with his pastoral staff. May many more personages like him come into control of our churches, synagogues, mosques, pagodas, temples and *Maths* the world over, for then the frequent tendency nowadays to bring science and religion into conflict may soon become a thing of the past.

or density of the universe as the data for calculations are still in the infant stage. So the weight of the universe as worked out here must be understood to be an extremely rough estimate which will be subject to revision from time to time in the light of further research.

With the last stages in these 'geodetic' measurements of the Universe, the great pilgrimage ends. A knowing, jolly critic may remark:—

'You remind me of the person of whom De Quincey said: "He had a smattering of mechanics, of physiology, geology, mineralogy, and all other ologies whatever." But you have left out many essentials in your wild attempt to deal with topics ranging from the ancient literature of the Aztecs to the geometrical properties of a rhombicosidodecahedron. Have you told us, for example, what may be the physical conditions at your so-called vault of space? Is it lighted by any gigantic lighthouses like those you have described? Or do these luminous worlds end too far below, so that this higher region is shrouded in perpetual cimmerian darkness for trillions and trillions of miles? Would the temperature there be absolute zero? Would the maxim that Nature abhors a vacuum be falsified and a perfect vacuum reign there? Would man, could he go so far up, keep flying about there somewhat like Japhet in search of a father, for eternity, free from the gravitational attraction of any heavenly body?

'You evidently accept with enthusiasm the mathematician's theory that Space bends *back* on itself and closes up as the earth's surface does, and is therefore *finite*, though unbounded. As for me, I frankly disagree. On my side is no less an authority than Pascal, who says that the universe is an infinite sphere, the centre of which is everywhere and the circumference nowhere. You may remember Emerson's remark that, if the East loves infinity, the West delights in boundaries. Einstein loves finitude, and delights in boundlessness! Emerson himself, had he been alive, would have been at his wits' end where to place him—East or West. Another great mathematician to-morrow may descend from his dizzy altitudes of thought with the theory,

which no known law of science [illegible] able to controvert, that *Time* also bends *back* on itself and closes up and is consequently finite, yet unlimited, and is *spherical*; that it rotates about an axis; and what is more, that he has put it on the scales and the reading is a split grain troy! I would however accept, in a fairly large measure but *only* in a metaphorical sense, such a theory for Time, for the term "*Old* Father Time" is drilled into my brain, and it is highly probable that

> "Bowed by the weight of centuries he leans
> Upon his hoe and gazes on the ground,
> The emptiness of ages in his face,
> And on his back the burden of the world."

To put it briefly in the mathematician's arid prose more bald than the head of Father Time, the Old Father bends *forward* on himself under the weight of years and the load of the universe, though you will agree that he is not sufficiently bent to look anything like spherical. I would even concede that Father Time is supple-bodied and also fat and bends *back* on himself instead of forward, until in the far, far future he closes up and becomes perfectly rotund, showing his face and forelock between his feet! The loftier the heights scientists reach, the greater becomes the frequency and the stranger the nature of theories. A fantastic theory was announced a few years ago about radiant energy—light and heat, and in that connection we are told by Jeans that the radiation emitted by a 50 horse-power searchlight working without break for a century will weigh about the twentieth of an ounce! So I shall not be surprised if men who have weighed protons and electrons and would have us believe that even light and heat are not quite imponderable, men who have weighed wireless waves and X-rays, turn their attention to Time next and announce, among other theories, that Time too has weight and weighs in troy grains, say, the square root of *minus* one!

'You seem to think that Jeans is England's Newton of to-day. There probably you are right, for his is a mind which has of late been, as Wordsworth said of Newton's, "voyaging through strange seas of thought, alone." The great physicist-mathematician-astronomer delights in telling us—and you may be believing it—that the

Creator of the Universe is a Pure Mathematician! For my part I can't deliver myself bound hand and foot into the hands of the mathematician, the physicist or the astronomer, the biologist or the geologist. *You* seem to have done so more as an ardent curio-hunter in this vast museum of the Universe.

'Let me now conclude my questions. Metaphors apart, if space and the universe are finite and coterminous, what lies beyond? What may space itself be floating in? Can there be any medium wherein it lives and moves and has its being? And if so, what medium can it be that supports this super-titanic load of the universe?'

Were the addressee to attempt to deal with questions of this character, he is afraid he would, to adapt a remark which a certain writer makes on the pursuit of metaphysics, be in the position of a blind man hunting in a dark room for a black cat which is not there!

CHAPTER XXIII

Astronomy in Asia up to the 18th Century

There is abundant evidence to show that the Hindus had attained proficiency in astronomy as far back as 3100 B.C. It was Mons. Bailly, the famous French astronomer, who first drew the attention of Europe not only to this hoary antiquity of Hindu astronomy, but also to the marvellous achievements of the ancient Hindus in this branch of science. In his remarkable work, *Histoire de l'Astronomie Ancienne,* published over 150 years ago, he says :—

> 'The Indians state that the world lasts for a period of four ages (*yugas*). The first age lasted 1,728,000 years, the second 1,296,000, the third 864,000, and the fourth or last, which is at the same time bound up with their astronomical epoch, has run 4,863 years in 1762 A. D.'—the date, probably, of the first edition of the book. 'The small number of years ascribed to the fourth age, in comparison with the vast period of duration of the first three, shows that the latter are fabulous or rather made up of years calculated on a basis very different from ours. But at the same time it is clear that the period of this last age is presented in solar years and based on a true historical epoch, which commenced in 3101 (B.C.). As, therefore, it is from this date that they (Indians) begin to calculate the movements of the sun, the moon and the stars, in longitude, it follows that that is also the date of their astronomy.'

But as human knowledge advances only step by step, the beginnings of this scientific culture among the Hindus must be traced still farther back, to several centuries anterior to this date.

The astronomical learning of the ancient Hindus has been acknowledged and admired by such eminent Western scholars as Count Bjornstjerna, Elphinstone, Weber, Wilson

and Hunter. It is indeed a wonder how in those bygone days the Hindus were able to pursue astronomical research without the aid of so valuable an instrument as the modern telescope.

We learn from Bailly that the Indian Tables of Solar Eclipses were sent by a French missionary of the Carnatic (Southern India) to France, where the astronomical observations recorded in them were carefully examined and found correct by French astronomers of the time. It was the Hindus too who for the first time applied to astronomy the principles of geometry and algebra, which two branches of mathematics were, in the opinion of so renowned a scholar as Sir Monier Williams, invented by the Hindus themselves. This can well be believed, as mathematics is the bed-rock of astronomy and Hindu astronomy has been admitted to be the oldest in the world.

To explain in detail or at any length the achievements of the Hindus in this science would take a whole volume. The earth's self-support in space, its rotundity, the length of its diameter, the equator, the earth's rotation on an axis, its gravitational force, the moon's rotation on an axis, its distance from the earth, the precession of the equinoxes, the lengths of the orbits of the planets, their mean motions, the calculations of eclipses, the sun's illumination of the planets, its gravitational force, the zodiac, constellations, stars of different magnitudes, the division of the ecliptic into lunar mansions, the split second in time measure, all these are included or dealt with in their system.

In the Concluding Remarks under the Stratosphere have been mentioned the names of some of the illustrious Hindu astronomers who flourished up to the 12th century A.D. The last of this galaxy was Bhāskarāchārya. Long after him came the famous Rajput Prince, Jai Singh II of Jaipur, an ardent and persevering astronomer, who lived only about two centuries ago. He caused several works on mathematics to be translated into Sanskrit, and built astronomical observatories at Jaipur, Muttra, Delhi, Benares and

Ujjain, which were equipped with instruments consisting of dials, azimuth circles, altitude pillars etc. Those in the Jaipur observatory, which are of a huge size, were put in order under the supervision of the Government of India in the first decade of the present century, probably during the regime of Lord Curzon. The Jantar Mantar of Delhi, an object of particular interest and curiosity to foreign tourists, must be familiar to those who have visited that city. It is typical of the few observatories in India erected prior to the advent of British rule. It was constructed in 1724 but was never completed owing to the death of its designer and the disturbed state of the Moghul Empire at the time. Even the portion that was finished was in later years seriously injured by the Jats and others, but Western scholars express the opinion that the remnants of the observatory which still stand reveal considerable astronomical skill on the part of its distinguished projector. Raja Jai Singh became so proficient an astronomer that he succeeded in correcting the Tables of the French astronomer De La Hire published in 1702. His researches culminated in the cataloguing of the various stars which he studied.

In Arabia the study of astronomy is similarly of a very ancient date. It is stated that the Almagest, a collection of astronomical observations and theories of the ancients drawn up by Ptolemy of Alexandria, which was regarded by the Arabs as the greatest and most complete work on this subject, was translated into Arabic by order of the Caliph Haroun-al-Rashid of Baghdad about 800 A.D. 29 years later, the Caliph Al-Mamun built a splendid observatory at Baghdad, which enabled Arab scholars to pursue their studies in astronomy. Distinguished Western scholars like Professor Weber and Sir William Hunter state that the Arabs became the disciples of the Hindus in the 8th century A.D. in the cultivation of this science. We are told that the Arabs borrowed from the latter the lunar mansions in their new order and translated in part, into their own language, Sanskrit treatises like the Siddhāntas with the assistance of Hindu astronomers invited by the Caliphs of

Baghdad to their courts. In the 13th century Ulugh Khan (died 1265 A.D.) founded an observatory at Maraga in Persia and equipped it with a mural quadrant 24 feet in diameter, along with altitude and azimuth instruments. About 1420, Ulugh Beg, a grandson of Tamerlane and the most famous of Tartar astronomers, established a grand observatory at Samarkand, in which he studied afresh all the stars dealt with in Ptolemy's book. He subsequently published a book of Astronomical Tables which held the field for two centuries.

It is well known that in olden times, besides commercial relations, there was close cultural contact between the Hindus and the Arabs. The fact that the Arabs became highly proficient in such difficult branches of science as mathematics and astronomy is a tribute to their great intellectual advancement in those days. Indeed, through the proficiency they attained in these fields of knowledge, they built up a fine system of nautical science.

As is well known, the term *Algebra* is Arabic in its origin. Similarly, there are a number of stars bearing Arabic names which have been permanently adopted in modern astronomy, *viz.*, Achernar, Aldebaran, Algenib, Algol, Alphecca, Alpheratz, Altair, Betelgeuse, Deneb, Denebola, Fomalhaut, Markab, Merak, Mizar, Rasalgeti, Rigel, Véga etc. The meanings of some of these names are given below.

Achernar, also written as Acarnar or Akharnar, which stands for *Akhir-annahr* = extremity of the river; *An-nahr*, the river, being the Arabic name of the Constellation, Eridanus. This constellation has the appearance of a winding river, Eridanus being the ancient name of the Italian river Po.

Aldebaran—Al = the, debarān = coming behind or following; so called, it is said, because it comes behind the remarkable group of Pleiades.

Algenib — means the reserve horse which is sometimes taken by a horseman for use when the beast he is riding becomes

fatigued. This star, it will be remembered, is in the Square of Pegasus, the 'Winged Horse'.

Algol—Al-ghūl = the ghoul or sylvan demon, namely, Medusa. Medusa's Head is the name of a cluster of stars in the Constellation of Perseus, which contains the bright star Algol.

Alpheratz—in Constellation Andromeda, which is between the Constellations Perseus and Pegasus. *Al* = the, *Faras* = the horse.

Altair or Alpha Aquilae in Constellation Aquila or Eagle. This constellation is called in Arabic *Naar-e-Tair* = the flying eagle, because its head is turned upward as if it is flying up.

Betelgeuse is a French name derived from the Arabic *Ibt-al-Jauza*; *Ibt* = arm-pit, *al* = the, *Jauza* = Constellation Orion.

Deneb — *Zanab* = the tail; the tail of the Dragon. Though belonging to the Constellation Cygnus or Swan, this star lies at the tail-end of the Constellation Draco or Dragon.

Denebola — *Zanab-al-Asad* = Tail of the Lion, the star being in the tail of the Constellation Leo.

Fomalhaut — *Fom-al-hut* = mouth of the large fish. *Fom, fam* = mouth, and hūt = a large fish. So called as this star lies in the mouth of Piscis Australis or Southern Fish.

Markab or Alpha Pegasi — means the saddle-place. This star is at the back of Alpheratz.

Rigel — *Rijil* = a person's foot, so called as this star is in the left foot of the Constellation Orion.

Vega in Constellation Lyra — *Wagi'* = falling. It is near the Constellation *Naar* or Aquila, Eagle. The star has its head turned towards the earth as if it is alighting on it, hence it is called *Naar-e-Wagi'* = falling eagle.

Astronomy occupied a prominent place in the cultural pursuits of the Chinese in ancient times. In fact, in China its advancement has for centuries been considered to be essential for efficient government. The date of the Chinese calendar goes back to very remote times, but it fell into confusion after some centuries, until the Emperor Hoang-Ti, with a view to correcting and bringing it up to date,

had an observatory built in 2608 B.C. Hoang-Ti appointed three committees of astronomers and entrusted them with observations of the sun, the moon and the stars respectively. He also instituted a Mathematical Tribunal to encourage the study of astronomy and to forecast eclipses. Astronomy flourished among the Chinese for a period of nearly 25 centuries extending from the reign of the Emperor Fou-Hi (2857 B.C.) to about 480 B.C. In Chinese literature are found accounts of the fall of meteors from the sky, running 26 centuries back; and one of the earliest recorded falls of a meteorite took place about 644 B.C.

The Chinese have recorded the fall of single brilliant fireballs as well as of showers of shooting stars. Professor F. R. Moulton of Chicago University says that they claim to have records of observations of sunspots made centuries before they were discovered by Galileo.

After 480 B.C. the tide turned and the science fell into neglect among the Chinese. In the days of the Caliphs of Baghdad, several Mahomedan astronomers migrated to China, where they introduced the astronomical knowledge and methods of the Arabs.

CHAPTER XXIV

Hindu Cosmogony and Cosmography

We propose to conclude with a brief exposition of some of the cosmological and cosmographical notions of the ancient Hindus.

'All religious theories, schemes and systems', remarks the great scientist Tyndall, 'which embrace notions of cosmogony, or which otherwise reach into its domain, must, in so far as they do this, submit to the control of science, and relinquish all thought of controlling it.' Were the searchlight of modern science directed on all the theories of creation propounded in the sacred books of the various religions of the world, we wonder how many of them would survive this rigorous test! It will not be too much to say that some of these theories, possibly many, must have been based on such rough data as the extent of scientific knowledge of the times could make available. The older a religion, the more difficult it becomes to interpret it in the light of modern science. Especially is this the case with the ancient Hindu theories of creation. It is difficult to imagine how a correct exposition of theories propounded by word of mouth only, as in the case of the Védas, about 5000 B.C., could be presented by commentators of dozens of centuries later. The only basis for arriving at a correct interpretation of all that was said in the Rig-Véda, for example, is the commentary of Sayana, who lived in the 14th century A.D. And he wrote it at a time when, owing to the lapse of some thousands of years, the ancient notions and conditions of the Védic age had probably ceased to exist.

The term 'Brahmânda' is defined in the sacred works of the Hindus as the primordial egg from which the universe sprang, or as *the universe itself*. According to *Manusmriti* (date about 200 B.C.), which gives an account of creation

based on a Rig-Védic hymn on the subject, the universe was, in the beginning, enveloped in darkness. The self-existent Lord, desiring to produce beings of many kinds from His own body, manifested Himself and dispelled the gloom. He first created the waters and deposited in them His seed, which became a golden egg having the brilliance of the sun. He himself took birth in that egg as Brahma (hence called *Hiranyagarbha*), the Progenitor of all the worlds. Then the Divine One, who dwelt in the egg, divided it into two parts, from which He constructed heaven and earth. He then created the ten Prajāpatis or mind-born sons, who completed the work of creation.

It may be noted that the name 'Brahmānda' as applied to the universe attributes to it an ellipsoidal form. Such a shape for the universe would not only imply finitude for space, but would resemble the spherical form which Einstein assigns to space, in one important particular, that the ellipse and the circle are both closed curves. But there are no data to substantiate the supposition that our ancients considered that the shape of the universe was similar to that of the egg out of which they believed it was formed. After the astronomical knowledge of the Hindus reached a high stage, the universe came to be also called 'Brahmagôla', a term first introduced in Sanskrit literature by the famous mathematician-astronomer, Bhāskarāchārya. This name would, of course, give the universe a definitely spherical form. Finitude for space is likewise assumed in Hindu mythology, which states that the universe has eight outposts guarded by *Ashtagajas* or eight elephants and each of these quarters is ruled by a Lôkapāla or regent appointed by Brahma.

There are various theories given about creation in the different Hindu sacred books. The Rig-Véda Samhita,* describing the order of creation, states that *Sat* (सत्), which may be defined as Reality, Entity or Existence, was first created; next came the directions or cardinal points of the compass; then came the Earth, which was followed by *Aditi*

(अदिति), meaning the boundless heaven, or according to some authorities, the visible infinite or the endless expanse 'beyond the earth, beyond the clouds, beyond the sky'. A more intelligible and connected theory was later on evolved by the sage Vyāsa out of the rather abstruse and outwardly inconsistent theories on the subject given in different places in the Védas (Upanishads). He explains in his Brahma-sutras that the first thing to be created was Akāsha (Ether or Space), which was followed in their due order by Vāyu (Air), Agni or Téj (Fire or Light), and lastly the Earth (which would include its Water). This theory is described by Vyāsa himself as the 'Pānchabhautika Srishti', a universe made up of the five elements, and it is stated that it was adopted by ancient as well as mediaeval Hindu savants. Vyāsa and other sages of ancient India were the first to enunciate to the world the principle of evolution. Our ancients had grasped the central ideas of Natural Science, and by doing considerable pioneering work, had paved the way for the moderns. They had made so much progress as to have evolved theories about the birth and age of the world, and the conservation, transformation and dissipation of energy. They did all this chiefly by the deductive method, and they also did observe and experiment. Our ancients also saw that there was one life pervading the whole of creation, and concluded that life was created and sustained by one Supreme Power.

The conception that all matter is built up of very minute, indivisible particles or atoms is said to have originated, so far as the West is concerned, with the Greek philosopher Leucippus who lived somewhere about 450 B.C., but the atomic theory in Ancient Greece was actually given shape and promulgated by his disciple, Democritus, though it was formulated on a scientific basis for the first time in 1808 by the British physicist, Dalton. Attempts in ancient times at an explanation of the material world took the form of the hypothesis that all matter is constituted of infinitesimal particles.

In India the oldest traces to be found of the atomic

theory are those contained in the Upanishads (date between 800 and 500 B.C.), whose total number is put down as 108. The Nārāyanôpanishad conveys some idea of the minuteness of the atom in its following description of the size of Atman (Self):—

अणोरणीयान् । महतोमहीयान् (Aṇôraṇīyān mahatōmahīyān)

which means:— 'Minuter than the minutest particle and bigger than the biggest (thing).' Later authors began to use without distinction either the one or the other of the terms अणु (anu) and परमाणु (paramānu—absolutely small particle) to denote the atom. For example, the former term appears in such works as the Bhagavadgītā, Manusmriti, Bhartrihari's 'Three Shatakas' and the Panchatantra, and the latter term in *Raghuvamsha* and *Tarkakaumudi*. Along with paramānu a few more synonymous terms came into use from time to time, *e.g.*, मात्रा (mātrā), कण (kana) and लेश (lésha). The atomic theory was called अणुवाद (anuvāda) and was defined as the doctrine that all material substances are primarily atoms and secondarily aggregates and that all atoms are eternal. Paramānus are described as spherical in shape (पारिमांडल्य, parimāndalya).

'Anu' in ancient works is made applicable not only to matter, but also to time. Thus an anu or atom of time represents 1/54675000th of a muhurta (48 minutes), which works out to about 1/19000th of a second. A fuller explanation of the sense in which the anu or atom was understood and applied in ancient times will be found in the *Encyclopaedia of Religion and Ethics* by Dr. James Hastings and in *Indian Philosophy* (Part II) by Sir S. Rādhakrishnan. It is to the latter source that the present writer owes much of his information on the subject.

The Upanishads generally looked upon all material substances as composed of the four elements, *viz.*, earth, water, light and air. Akāsha (ether) is excluded owing to its peculiar nature and the fact that it does not enter into combination with the other elements. As Rādhakrishnan explains it :—

'The four elements of light, water, air and earth are themselves changeable and divisible, while the real is regarded as unchangeable and eternal. The question naturally arises as to what the unchangeable, indivisible, eternal particles are. In the ferment of thought which produced the great systems of Jainism and Buddhism, there were some who held the atomic hypothesis, for example, Ajīvakas and the Jainas. Kaṇāda formulated the theory purely on metaphysical grounds and tried through it to simplify the world of thought. . . . .

'All things consisting of parts originate from the parts with which they are connected by the relation of inherence, conjunction co-operating. The things that we experience are all products, *i. e.*, discrete or made up of parts. They are therefore non-eternal. Non-eternal has no meaning apart from eternal. Earth, water, fire and air are both eternal and non-eternal, while ākāsha is eternal only. The compounds which are produced are non-eternal, while the component particles which are not produced are eternal. The invisible eternal atoms are incapable of division into parts. The atom marks the limit of division. If it is endlessly divisible into parts, then all material things would be the products of an equally endless number of constituent parts, so that differences in the dimensions of things cannot be accounted for. If matter were infinitely divisible, then we should have to reduce it to nothing, and admit the paradoxical position that magnitudes are built up of what has no magnitude, bodies out of the bodiless. . . . .
It is assumed that there are four classes of paramāṇus, answering to the four great classes of material objects, earth, water, light and air. These four classes of paramāṇus are said to produce the four senses of touch, taste, sight and smell, and this is why each special sense reveals a single quality, however excited. Though the qualities of earthly things, as colour, taste, smell and tangibility, vanish on the destruction of the thing itself, they are always found in their respective atoms, though in earth and atoms of earth some qualities are produced by heat (pākaja). Water, light and air do not suffer a similar change . . . . .

'The atoms are naturally passive, and their movement is due to external impact, ...

'The qualities of all products are due to the atoms of which they are composed. These atoms possess the five general qualities of all substances, as also those of priority and posteriority. In addition to these, earth has the special quality of odour and the other qualities of taste, colour, touch or temperature, heaviness, velocity and fluidity. Water has the special quality of viscosity and the other qualities of earth except smell. Light has the usual seven, and temperature, colour, fluidity, and velocity, while air has only touch and velocity in addition to the seven common qualities. These qualities are eternal in the atoms, but transient in the products. . . . . . .

'In Greece as well as in India, the hypothesis (atomic) was put forward as a metaphysical one and not a scientific principle.'

The atomic theory forms an integral part of the Vaishéshika system of philosophy, a system to which Rādhākrishnan assigns a date between the 6th and 5th centuries B.C., *i.e.*, about the time of Buddha and Mahāvīra. It is chiefly a system in which both physics and metaphysics are combined, but its standpoint is more of a scientific than of a speculative character. The first exponent of the Vaishéshika in a systematic manner was the great philosopher Kanāda, a nickname which etymologically means 'eater of atoms'!

According to the Purānas, in the *Svayambhu* or first period of creation, there were two types of matter—Elements and Compounds—called *Sarga* (primary matter) and *Pratisarga* (secondary or continued creation out of primary matter), and in the latter again creation progressed in the following order:—(1) Minerals (धातवः Dhātavah), (2) Plants, described as Urdhwa Shrōtas (ऊर्ध्वस्रोतस्), organisms whose stream of life or current of nutriment tends upward; (3) Animals, called Tiryak Shrōtas (तिर्यक्स्रोतस्), creatures whose stream of life or channel for conveying food tends transversely or obliquely, and (4) Men, described as Arvāk Shrōtas (अर्वाक्स्रोतस्), beings in whom the current of nutriment tends downward. Interpreted in terms of geologic chronology, the inanimate

creation represented by Minerals will have commenced in the Azoic Age, Plants and Animals begun to form in the Palaeozoic or Primary Era, continuing higher and higher in the scale of organization in the Mesozoic (Secondary) and Cainozoic (Tertiary) Epochs, and Man come into existence in the Post-Tertiary period. So the Purānic order of creation on the earth is in general accord with the modern theory of evolution.

According to the Purānic computation of the length of geologic time, the age of the earth at the date the Purānas were written was 1,960,853,034 or very nearly 2 billion years, a value which, it is interesting to note, is as good as identical with the estimate of present-day geologists.

Now a few words about the geography and cosmography of the ancient Hindus.

The Purānas (date between 400 and 800 A. D.) contain divergent descriptions of the geographical divisions of our globe, the most important being the one given by the sage Parāshara in the Vishnu Purāna, the 3rd of the 18 Purānas. According to it, the earth's surface is divided into Saptadvīpas or seven island continents and Saptamahāsāgaras or seven great oceans. The continents are Jambu, Plaksha, Shālmali, Kusha, Krauncha, Shāka and Pushkara, each being separated from the next by an ocean. The oceans are named Kshārasamudra, Ikshurasôda, Surāsamudra, Ghritôda, Kshīrasamudra, Dadhimandôda and Shuddhôda—seas of salt water, sugarcane juice or syrup, spirituous liquor, ghee or clarified butter, milk, curds, and fresh or sweet water respectively. Jambudvīpa lies in the centre of all these. And according to Hindu theogony, in the centre of this continent, towering thousands of yōjanas (a yôjana being equal to about 5 English miles) into the skies, is the golden mountain Méru, the Olympus of the Hindu gods. It is like the seed-cup of a lotus and is the navel of the earth, and on different peaks of this mountain reside the gods. Six boundary mountains, each of fabulous size and height, surround the earth. The earth's surface is

thus presented as a series of concentric circles of land and water.

'A mythical mountain named Lôkālôka girdles the globe. It rises beyond the ocean of fresh water which surrounds the last of the continents; to the earthward side of this mountain there is light, but on the opposite side reigns utter darkness. Lôkālôka thus divides the visible world from the regions of darkness.' Thus is it said in 'Raghuvamsha', 'Shishupālavadha' and 'Mahāvīracharita'. Here may be quoted a definition of the finitude of the earth in terms of modern scientific thought. 'The surface of the earth', says Lodge, 'has no boundary, no watery edge over which a navigator might sail. And yet, the earth is finite in extent and of easily calculable area.' The earth has thus no brink anywhere from which a curious globe-trotter could indulge in the luxury of gazing into an unfathomable abyss beyond!

Most of the seven continents named above cannot now be definitely identified for several reasons. Says Sarda in this connection :—

> 'Owing to the destruction of the greater part of Sanskrit literature (by acts of vandalism by invaders), it is impossible now to interpret correctly these geographical facts, not only because these are only the fragmentary remains of geography inextricably mixed up with Purāṇic mythology and theology, but to a great extent because many of these ancient Dvīpas and countries have been so materially altered in consequence of the cataclysm called the Deluge, as to have become impossible of identification now.'

But notwithstanding these difficulties, efforts have been made in recent years by some scholars to piece together these remnants and identify the various land and water divisions of the globe as known in modern geography. In 'Bhāratavarshīya Prāchīna Charitrakôsha,' a very recent work in the Marāthi language by Vidyānidhi Siddhéshwar Shāstri Chitrāva, the author gives the conclusions arrived at by him on the basis of geographical theories or hypothe-

ses said to have been put forward by geologists based on the changes which the earth's surface has undergone from age to age. He also gives side by side the conclusions of other well-known scholars like Mr. V. K. Rājwādé, which, however, in most cases materially differ from the author's. He annexes a detailed map showing the various land and water regions that made up the earth's surface in the age to which the Purānas refer. It is not possible to say without a careful and critical study how far his conclusions are acceptable. Space forbids us from giving all the details, but we may give a few of those relating to the continent to which India belonged.

Jambudvīpa is made up of India, Afghanistan, Eastern Persia, Siberia, and China excluding the sandy regions of Mongolia, and is surrounded by Ksharasamudra, which is made up of the Indian Ocean, Persian Gulf, the Caspian Sea, part of the Arctic Ocean, and parts of the present land regions in between the last three bodies of water which formerly lay under the sea.

The countries composing Jambudvīpa were Ilāvratta (near Pāmir Plateau), Kétumāla(Northern Iran, Turkestan, Afghanistan and Baluchistan), Bhadrāshva (Mongolia, Manchuria and the Chinese district of Zungaria), Kimpurusha (Tibet), Bhārata (India*), Harivarsha (Siam, Burma and China), Kuru (Siberia), Hiranmaya (southern parts of Russia like Trans-Caucasia), and Ramyaka (Russian Central Asia). This continent has nine important mountains: Gandha Mādana (Elburz), Méru (Pāmir), Shvéta (Tien-Shan), Ramanaka (Altai), Hiranyaka (Yablonoi), Shringavata (Stanovoi), Hémakuta (Kuen-Lun), Himālaya, and Nishadha (which includes Patkoi Hills, east of Assam; Lushai Hills in southern Assam; and Arakan Mountains in Burma).

India or Bhāratavarsha, according to another authority, contains seven important mountain ranges: Mahéndra (in Orissa), Malaya (southern portion of Western Ghats), Sahya (Sahyādris, the northern portion of Western Ghats), Shak-

timān, Gandhamādana, Vindhya (Northern Vindhyas) and Pāriyātra (Western Vindhyas), and the following seven rivers :—

(1) Shōnabhadrā
(2) Sindhu — Indus
(3) Hiranyavāha — a name which, in its etymological sense, means 'bearing or carrying gold or silver'. It is identified with the river Sone, a tributary of the Ganges, which rises on the plateau of Amarakantak or *Gondwana* in Central Provinces and falls into the main river below Pātaliputra near the modern city of Patna.
(4) Kōka
(5) Gharghara — Ganges
(6) Lōhita — Brahmaputra
(7) Shatadru — Sutlej

It is difficult to identify definitely two of the mountain ranges and two of the rivers.

There are different theories about the location of the Holy Mountain Méru. Parāshara, as above stated, says that it stands in the heart of Jambudvīpa. A second theory is that Méru consists of the highlands of Tartary immediately north of the Himalayas, meaning no doubt the plateaux of Tibet and Pāmir. Méru, according to Bhāskarāchārya, is the abode of the gods Brahma, Vishnu and Shiva. But on the whole there is unanimity in attributing to it fabulous size and height. One authority describes it as a mythical mountain said to consist of gold and gems and around which the planets revolve. Among the innumerable names of the god Shiva are Mérudhāman and Kailāsanāth. The former means 'He whose abode is Méru', and the latter 'Lord of Kailās'. In 'Méghaduta' and 'Raghuvamsha', Kālidāsa describes Kailās as a peak of the Himalayas and residence of the gods Shiva and Kubéra. The fact that Méru in some works and Kailās in others are represented as the abode of Shiva, and that the sacred Mānasarōvar, one of the lakes from which it is said the gods drink, lies in the vicinity of the Holy Mount of Kailās, has led some Western writers to conclude that the two mountains are identical. Tilak expounds the view

that Méru is the terrestrial North Pole of the Hindû astronomers, and in support of it quotes, among other authorities, a line from Surya-Siddhānta which means:—'At Méru the gods behold the sun after only *a single rising* during the half of his revolution beginning with the zodiacal constellation Aries.' He adds that the description of Méru given in Vanaparva of the Mahābhārata leaves no doubt that this Holy Peak is the North Pole or at any rate possesses polar characteristics.

The universe consists of three main worlds: Heaven, Earth and Hell, but according to fuller classification, the number of worlds is fourteen: seven upper and seven lower. The upper worlds, ascending one above the other, are :—

(1) Bhûrlôka — The Earth

(2) Bhuvarlôka — The Region between the Earth and the Sun, which would include the whole Atmosphere, the Moon and the planets Venus and Mercury.

(3) Svarlôka — The Heaven of the god Indra, and temporary residence of the virtuous after death, being the region between the Sun and the Pole Star (Dhruva), which would include in it the superior planets and a number of stars.

(4) Maharlôka — *The World of Light and Lustre*

(5) Janarlôka — The Heaven of the Deified Mortals and residence of the sons of Brahma.

(6) Taparlôka — The Heaven of those holy sages who have attained the nature and qualities of the gods by austere devotion.

(7) Satyalôka or Brahmalôka — The Heaven of the god Brahma.

Different definitions of these worlds appear in different works. Bhāskarāchārya, for example, in 'Bhuvanakôsha', defines Bhurlôka and Bhuvarlôka as the two halves of the earth, its southern and northern hemispheres respectively, and Svarlôka as none other than the Holy Mountain Méru, 'the abode of the gods Brahma, Vishnu and Mahésh'. We have however given preference where possible to only those definitions of these worlds which would be intelligible from the astronomical point of view. The light of the sun illumines Bhurlôka, Bhuvarlôka and parts of Svarlôka and does

not travel beyond. Maharlôka, the World of Light and Lustre, would indeed be a glorious and fitting name for that vast region of the heavens which is illuminated by such titanic 'lighthouses in the oceans of space' as Maghā, Rôhini, Purvābhādrapadā and Ardrā (Regulus, Aldebaran, Scheat with Markab, and Betelgeuse respectively), but we have no sufficient data for so grand an inference or assumption. The remaining three worlds rise one above the other between the outer boundary of Maharlôka and the vault of the universe, Satyalôka or Brahmalôka being the last and uppermost. It is said that Yôgis, Tapasvis and Sanyāsis go to Maharlôka, Janarlôka, Taparlôka and Satyalôka according to their merit.

The seven nether worlds are Atala, Vitala, Sutala, Rasātala, Talātala, Mahātala and Pātāla, descending from the earth one below the other, and are inhabited by Dānavas (demons). Pātāla, the last of these, is peopled by Nāgas or serpent-demons, but the Vishnu Purāna gives a graphic description of the beauty and attractions of this world. The same work says that, above all these fourteen worlds which make up the universe, lies Vaikuntha, the abode or Heaven of Vishnu, though Bhāskarāchārya is content to locate it on the Holy Mount of Méru. It is stated that even the gods cannot describe the splendour and glories of Vaikuntha. Vaikuntha is however separated from our universe by the Virajā river, which is said to be 10 crore yôjanas, (equal to 500 million English miles) in length and 1 crore yôjanas (50 million miles) in breadth. 50 crore yôjanas (2½ billion miles) above Vaikuntha, again, lies the last and highest Svarga or Heaven, the Gôlôka—the Hindu Empyrean—which too is a world of indescribable splendour.

A few words about the Védic universe. The question has often been asked where the Védic divinities dwelt. They must have had a universe in which they lived and moved and had their being. Several hymns in the Rig-Véda mention this universe as Earth, Sky and Heaven. In his work, *The Vedic Gods—As Figures of Biology*, Dr. V. G. Rélé deals exhaustively with this subject from a scientific

standpoint. 'The Védic world', he says, 'is elongated, the two halves being placed side by side to run a parallel course. The two bowls of Heaven are perched on the earth as on a pole, and there is cleavage in the heavens. The *Antariksha* (sky) is filled with water and has mountains and streams in it.' In other words, the Védic universe consists of two halves rising vertically and parallel to each other, each half having its earthly, aerial and heavenly regions, and each region in the one half being united with a similar region in the other half. The universe thus presented would be somewhat like a pair of scissors standing on its apex. As the author describes it, it is fashioned like a tree. Varuna, the god of waters, is said to hold its stem on the unsupported region, and its roots are high above in the heaven. The Védic universe would thus be different from the external universe known to us. Rélé gives a physiological explanation of this seeming difference. He propounds the view that the Védic deities have an anatomical origin and are personified in the various parts of the human nervous system, quoting in support of it Susruta's theory that the Védic gods have their permanent abode in the human body. He thus identifies the Universe of the Védas (the Rig-Véda) with the nervous system of man, the Earth representing the spinal cord, the Védic heaven the brain, the Antariksha the point where these two meet, and it is in this universe that the Védic divinities reside. He explains, on the biological hypothesis, the strange appearances of these gods. He also interprets the various legends associated with them with the help of physiological and embryological data, but a proper and fuller understanding of the whole subject is possible only by a perusal of the book itself. The theories he advances in it afford food for thought and material for further research by Védic scholars, particularly those who are fairly conversant with the sciences of embryology, human physiology and anatomy.

There are still among us people, whose number is however decreasing, who are given to indiscriminate adulation of our ancient institutions and blind admiration of everything in

our ancient culture. Side by side there is a tendency among many of us to look upon our cosmogonical traditions in a light-hearted spirit or even to disbelieve them totally. This attitude is due to the fact that many of these traditions have been so diversely interpreted by different authors or commentators that the key to their interpretation has been lost, and to many of us they are like a tangled web practically impossible to unweave. Here may be quoted an illuminating remark about these traditions made by so cautious a scientific authority as Sir Charles Lyell, who says in his *Elements of Geology*:—'We can by no means look upon them as a pure effort of the unassisted imagination, or believe them to have been composed without regard to opinions and theories founded on the observation of Nature.' In his book, *Is India Civilized?*, Sir John Woodroffe remarks that the theory of man's evolution held by the ancient Hindus was not, like the modern doctrine, based entirely on observation and a scientific inquiry into fact, but was rather (*as in some other matters*), an act of brilliant intuition in which observation may also have had some part. In the light of these two remarks, it is possible to understand, to some extent at least, the bases on which the cosmogonical notions of the ancient Hindus were founded.

Sir Oliver Lodge, it is of interest to note, says that the earth may be expected to have an end, 'though what the end may be we have at present no idea.' From some of the astronomical chapters of this book it will have been noticed that, according to modern scientists, the earth—or rather life on it—may come to an end as a result of any one of the following catastrophes:—

(1) Collision of the earth with the nucleus of a comet, according to Gregory.

(2) Collision of the earth with an asteroid, according to Jeans and Gregory.

(3) The gradual extinction of the sun owing to its continually losing mass at a tremendous rate, reference to which is made at the end of Chapter XII.

In the last case life would of course have been blotted out of the earth billions of years before the annihilation of the sun, on account of the quantity of solar radiation available to the earth at a certain stage becoming absolutely insufficient to sustain life. Peering into that abysmal future, what would be the fate of this lifeless earth when the sun is gone? Long before the entire destruction of the sun its mass would have shrunk to such an extent that all the planets and planetoids would break away from its gravitational pull, so that the whole population of the solar system—the satellites accompanying the parent bodies—would dash out into space, careering along with the comets as so many road-hogs of the universe! These frozen ex-members of the solar system would then be lighted only by the stars and enveloped in perpetual night. It would take millions of years for the complete disintegration and annihilation of the earth itself owing to the great density of its material, but once the earth becomes a derelict, life cannot reappear on it.

But the end of the sun or of its family does not mean the end of the universe, nor even of that astronomical universe, our own galaxy, of which the sun is a member. The end of the universe, explains Jeans, will come when every atom capable of annihilation has been annihilated and its energy transformed into heat-energy wandering for ever round space and when all the weight of any kind whatever which is capable of being transformed into radiation has beeen so transformed. This means that a time will come when nowhere in space or the universe will exist anything in a solid, liquid or gaseous state, for even the atoms will have broken up and the universe become one vast ocean of radiation distributed equally and at a uniform temperature. As it is believed that matter can never re-form itself from radiation, the universe then becomes a featureless, matterless and virtually empty and weightless ocean of space, and time in the ordinary sense disappears into eternity, a changeless eternity except possibly for the continued expansion of spaee, for, as Eddington explains, radia-

tion will become thinner and thinner, passing into larger and longer wave-lengths. 'So the end of the universe', remarks the physicist Dr. R. L. Waterfield, 'will be much like the beginning — a timeless, unchanging eternity. But whereas the first eternity is a homogeneous chaos of gas, the last eternity is a homogeneous chaos of radiation. And since we believe radiation can never change back into matter, the first state is like a clock wound up waiting for a chance wind to set its pendulum in motion, while the last state is like a clock run down, waiting for the chance that can never come to wind it up again.'

In juxtaposition with these conceptions of modern science as to the ultimate fate of the earth and the whole universe, may be placed the ancient Hindu theory of 'Mahāpralaya' or 'Brahmapralaya' — the Great Dissolution or Destruction of all Creation — which is said to occur at the end of Brahma's life period amounting to 100 Brahman or divine years. According to Atharva-Véda, a Brahma Din, a day of Brahma, is equal to 4,320 million mortal years. If to this is added a like value representing the term of a Brahma Rātri or night of Brahma, we find that a full twenty-four-hour day of Brahma or *Kalpa* as it is called, is equal to 8,640 million years. The life period of Brahma, 100 divine years, called a Mahākalpa, will thus amount to 315,360,000,000,000 or a little over 315 trillion mortal years. This then will represent the full span of life of the universe. About the present age of the universe, modern science in trying to give us an idea places before us values selection from which is very difficult. At the end of Chapter XX have been given two estimates, one coming from an all-round scientist of world-wide distinction, and the other, probably the latest, from a scientist who may not be so well known. But these estimates of 200 trillion and 3 billion years respectively are as poles asunder.

According to the Hindu Scriptures, there are two major Pralayas or dissolutions: (1) *Naimittika*, occasional or

incidental destruction of all creation, of all that lives and has a form, but not of the substance. The substance remains *in statu quo* till the new dawn in that night (Brahma Rātri). The universe is thus alternately created from and dissolved into its material cause at the end of every Brahma Rātri and Brahma Din. The Vaishéshika philosophy calls this intermediate destruction Avāntara-Pralaya, 'avāntara' in Sanskrit meaning 'secondary'. (2) *Prakrittika* or Mahāpralaya, the Great or Universal Dissolution, which occurs at the end of the life period of Brahma. At the Mahāpralaya all the worlds with their inhabitants as well as the gods will be annihilated. So then life is re-created in the various worlds out of the substance of the universe at the end of each Naimittika Pralaya and finally disappears at the Mahāpralaya. In this final Pralaya everything in the universe, material as well as immaterial, is resolved into the atoms, and as the Vaishéshika says, the atoms then subsist without producing any effects and remain isolated and inert. Even the gods Brahma and Shiva are not spared, for like the rest of creation they are created out of matter and must dissolve with matter. Tennyson so appropriately remarks:—

> 'If all be atoms, how then should the gods
> Being atomic not be dissoluble,
> Not follow the great law?'

To what extent there may be bases for the Hindu theory and for the seemingly arbitrary periods fixed by our ancients for these possible Pralayas, we are not in a position to say. Average mortals like us can only indulge in mathematical diversions by taking the ancient Hindu theories with modern Western ones where convenient! Accordingly, in the light of the theory that this universe will some day come to an end as the result of a Mahāpralaya, or a 'heat-death' according to Jeans, or the 'bursting' of an expanding space like a soap-bubble, a possibility vaguely or hesitatingly hinted by Abbé Lemaître, or like a toy balloon to borrow Eddington's simile, we venture to present such of our readers as may believe the theory of space-

expansion as well as that of Mahāpralaya, with a problem perhaps more fantastic than any that can be found or conceived in the whole range of mathematics :-

> 'If the universe is now 3 billion years old, if its span of life is 315·36 trillion years, if space doubles its diameter every 1,400 million years and if the present radius of the universe is 70 sextillion miles, what should this radius be at the Mahāpralaya ?'

There is no harm in attempting the answer! This is a simple sum in Geometrical Progression. We find that the balance of life which the universe has still to run is 315·36 trillion *minus* 3 billion years = 315,357 billion years. The common ratio is 2. The first term is 70 sextillion, and the number of terms in the whole series is $\frac{315357 \text{ billion}}{1400 \text{ million}}$ = 225,255 nearly. Applying the relative formula, we find that the last term of the series, in other words, the radius of the universe at the Mahāpralaya, will be 70 sextillion $\times 2^{225254}$ or countless decillions of miles!

The Pāingala Upanishad tells us that, at the Final Dissolution, the Brahmānda or primal universe and its effects the worlds are drawn in into their cause, the subtle organs of sense and action and the four internal organs mixed together, and all things composed of the elements are resolved into their primal elements. The Earth is resolved and drawn in into Water, Water into Fire, Fire into Air, Air into Ether, Ether into Egoism (Ahankāra), Egoism into *Mahat* (Secular Reason or Intellect), *Mahat* into *Avyakta* (Prakriti, the primary germ of Nature or productive principle out of which all the phenomena of the material universe are developed), and lastly *Avyakta* into *Purusha* (the Supreme Spirit). Like Space and Matter, Time also is swallowed up in Him, and the Supreme Being becomes then the Eternal, Universal and Unconditioned Time. The Anādi Vaikuntha, the Heaven of Vishnu which has no beginning, with its souls enjoying *Jivanmukti* (Living Freedom), and even the gods Brahma, Vishnu and

Ishwara, emancipated from the vehicle of Māyā (Illusion), are absorbed into or reunited with Paramātman (Supreme Self). God is thus both the efficient and material cause of the universe, that is to say, is the source of the whole universe as well as the place whereinto it dissolves again. In other words, the universe is a projection of the Lord, or the Lord Himself.

ADDENDA & CORRIGENDA

Chapter II, Item 19, pages 39–40

In the Note under this item appears the remark that, in the opinion of American engineers, it is possible to construct a steel sphere which can go down, with divers inside, to even half a mile beneath the ocean surface.

It is now reported in the *New York Times* and the *Chicago Daily Tribune* that Beebe and Barton quite recently succeeded in penetrating to this record depth in a steel bathysphere 4 ft. 6 in. in diameter and 1½ inches thick, provided with three protruding port-holes of fused quartz panes 8 inches in diameter and 3 inches thick. Attached to the sphere was a powerful searchlight. The descent was made from a ship 10 miles off the coast of Nonsuch Island in the Bermuda group. As they descended into the watery abyss, they broadcast their sensations and a graphic description of the undersea life they saw to thousands of radio listeners in America. They also took motion pictures at the bottom of the descent. The pressure here was 80 atmospheres or over half a ton to the square inch. Beebe once remarked that, if such a pressure were loosened for the fraction of a second on a human being, he would be reduced to amorphous tissue!

At this great depth the explorers found themselves in a 'cold, green, dimly lighted world'. The spectroscope registered zero sunlight, but they could see from time to time without using the searchlight owing to the myriads of luminous fishes that flashed past them! These fishes illuminated the waters with varied tints of pale green or pale blue. At one moment the sea became 'as black as Hades', and at the next the scientists were in the midst of 'a brilliant iridescence'. They closely observed the strange varieties of fish around them as they came within the range of the search-light beams. In his radio message to the *New York Times*, Beebe announced that the scientific results of the descent were most satisfactory.

ADDENDA & CORRIGENDA

Chapter III, Item 49, page 93

Subsequent investigation shows that the title of Varman adopted by the Hindu rulers of Borneo was not confined to the Pallavas of Southern India. It was also assumed by the Sailéndra kings of Shrī Vijaya, who themselves might have adopted it from the Princes of Kashmir some of whom bore that title.

Chapter VII, Item 5, page 206

The date on which Capt. Uwins set up the aeroplane altitude-record was the 16th of September 1932.

Chapter VIII, Item 3, page 213

In an article in the *Times* (London) of 8th October 1932, Dr. Piccard gives the highest altitude reached by him in his second ascent as 53,672 ft. (10 miles 1 fur. 71 yds.).

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